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A POPULAR GEOLOGY

BY

WILLIAM PLATT

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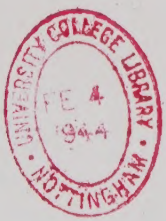

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INTRODUCTION

In that inspired and glorious poem, the Book of Job, the various misfortunes that afflict mankind are vividly, poignantly discussed; the problem of suffering, and the kindred problem of evil, are presented and debated; the book proceeds; for a long while no solution is reached—nay, hope of solution seems farther and farther off.

Suddenly, in a dramatic and overwhelming intervention, "the Lord God answered Job out of the whirlwind." And in the sublime magnificence of that answer, there is not one single word about the sorrows or sufferings of Job. The answer is concerned solely with the marvels of the Universe, made "when the morning stars sang together, and all the sons of God shouted for joy."

The moral is as necessary as it is inspiring. We are not isolated creatures, sent each to play his solitary part. We are fragments, minute enough, of a grand whole, the immensity of which we only dimly perceive.

If we brood over our own troubles, little or big, deserved or undeserved, we are likely to become slaves to one or another of those neuroses of which we hear so much to-day. But if we can, at times, withdraw ourselves, lose ourselves in the supersublime immensity of the eternal pageant of the Universe, we can save our souls alive in such communion with God.

One part of this universal pageant is unfolded to us by the deeply interesting science of Geology. Like every other well-developed science, it needs, and has

acquired, a formidable vocabulary of technical terms. It is the object of this little book to explain a few of its wonders very simply, in a way that can be understood by everybody, beginning with what is seen, or can be seen, by almost everyone, and going thence by easy stages to the deeper and wider facts. If this booklet leads any reader to profounder studies, all the better. But at the very least it is hoped to give some idea of a most interesting and absorbing science, to show new aspects of daily surroundings, to add a zest to journeys and excursions, and to tell, if only in a whisper, one or two little tales from the store of the marvellous Universe.

W. P.

4, Hallswelle Road,
Golders Green,
London.

A POPULAR GEOLOGY

CHAPTER I

CLAY, SAND, AND GRAVEL—LONDON

WHAT kind of district do you live in? Whatever it is, you will be interested to learn something about the geology of it—about the soil or rock, and how it came there.

Let us suppose, to begin with, that you live in a town, built on a rather flat plain, chiefly of clay, but with a few stretches of sandy soil and occasional patches of gravel. Such a combination can be found in every country in the world. There will be a river running through this plain of clay, near the middle; small tributaries will run into it from both sides.

When such conditions arise, the *general* causes may be similar in most cases, but the *details* will differ every time; so that it will be wiser to take a real example, and what better one than London?

Let us, then, suppose that you are a Londoner; what are your difficulties if you wish to know something about the geological history of the clay plain on which London is built? In the first place, London ground is covered up by houses and paving-stones; even the gardens have an artificial topsoil; it seems almost impossible to know what the ground was like before the huge town sprawled all over it. That is a very great and very real difficulty; but it can be overcome.

For instance, you know by hearsay that most of London is built on clay; you may occasionally see diggings, for various purposes, that go right into the ground; you can see in many places what the banks of

the Thames are like; you can see a good deal of the natural ground in the parks; and, most important of all, it is easy to reach the outskirts, and to study there the unspoilt, natural country. But you will probably not learn much by yourself, unless there is some person or book to answer your questions.

What is London Clay? You can see for yourself if you watch the banks of the river at its lowest, or if you visit Southend when the tide is out. London Clay is simply Thames mud. London owes to her mighty river not only her commerce, but also the very ground on which she is principally built. But the London Clay covers a district which, measured from north to south through London, has a width of over twenty-five miles; while in places it is over 400 feet thick; how long would it take even a great river to bring down mud enough for this?

Let me point out one thing. It is no use, in Geology, saying, "I cannot believe it; it is too vast; it would have taken more time than I can believe possible." God has eternity. We cannot sum up vast natural processes by our petty notions of time. As soon as we satisfy ourselves that London Clay is river mud hardened by time and pressure, we must allow for its formation as much time as is needed, even though it should run into a million years. It might not require this amount of time. There are many far vaster formations in Geology. I am only here stating a sound general principle.

However, the farther we look into this question of the London Clay, the greater the problem grows. We find underneath this clay both sandy and pebbly beds (called *Thanet Sands, Woolwich Beds,* and *Blackheath Beds*), with which it is associated; and we find above it sandy beds (called *Claygate Beds* and *Bagshot Sand*) which also clearly belong to the same series; this series is called "Eocene." The word *Eocene* is from the Greek, and means the *dawn of recent life*.

Taking this Eocene formation altogether, our first task must be to discover how far it extends. Measured

across the middle of London, it is over twenty-five miles wide, and in places over 400 feet thick; but further study of the facts shows us that a similar formation stretches right down into Hampshire, the Isle of Wight, and a corner of Dorsetshire (with a break where the Hampshire chalk hills come through, certainly; but then it can be proved that the Eocene at one time covered them); while in the eastern direction it reaches Belgium and Northern France, coming right up to Paris itself, and forming the historic soil of places deeply engraved in our British memories, such as Ypres, Tirlemont, Louvain, and Mons. The historic clay of Flanders is, to the geologist, an extension of our London Clay.

We have to deal, then, with deposits that were undoubtedly brought down by rivers, grain by grain, as mud, sand, and silt; and these deposits stretch from Dorchester to Ipswich, in England, and across the Channel, through Ostend, across Central Belgium to Tirlemont; then downwards over Northern France. From Dorchester to Tirlemont is 300 miles. Truly the Eocene of which the London Clay, with its accompanying sands, is a part, is a matter to be thought about.

And not only was this immense mass of silt deposited here by river action; it can be equally proved that much has since been worn away again by reverse action; for in many parts, as in Hampshire and Northern France, the rocks that were once underneath the Eocene are now standing out again, bared of the silt that once lay over them, as geologists know. Let us examine a few known facts as to the amount of silt that a river can bring down with it. Clay and sand consist of small grains torn off the older rocks by water, frost, heat, wind, ice, or chemical action in the air, and carried usually by rain or river to lower and lower levels till some obstacle, such as a lake, lagoon, sea-bay, or coast-line with its opposing tides, stops the flow of the river and causes it to drop its burden. Every stream and river carries silt, and is coloured by

it. How much does it carry, remembering that its movement is ceaseless, every minute, every hour, every day?

When I was head master of a boarding-school in Derbyshire, we had an open-air swimming-bath fed by a natural spring, which in ordinary times only brought down a small trickle of water. Its average rate was about 200 gallons per hour; that is to say, it would take a second to fill a half-pint tumbler. Standing as it did in full sunshine, it only needed clearing out occasionally. After six months there would be found in it from twelve to twenty barrow-loads of sand and soil—just from one little spring.

In Mesopotamia, the town of Eridu is at present 130 miles from the sea. But the history of this region goes back for a long time, and we know that Eridu was a port, on the Persian Gulf, 8,800 years ago. This proves that the combined rivers, Euphrates and Tigris, have been making land at the rate of about a mile in the lifetime of a man.

This makes more understandable the building up of the Eocene Clay and Sands in what must have been a large lagoon, 300 miles long. More than one river emptied its contents into that lagoon. The French and Belgian parts must have been derived from rivers flowing in at that eastern end.

The Dorset and Hampshire end was probably supplied by a large river from the west; perhaps the English Channel was not then in existence; a strong barrier of rocks, from Cornwall to Brittany, may have held back the sea, and a river may have wandered along a low plain, that has since been submerged, to the south of our present Britain. At the end of the great lagoon—that is, somewhere near where Reading now stands—the work must have been done by the mighty Thames, a much bigger Thames than we know now. Careful examinations in the West of England, among the Cotswold Hills, have proved to us that in days long past the rivers of Mid-Wales were tributaries of the Thames, and not of the Severn. The

swift little Severn, cutting its way back more rapidly than the larger but slower Thames, stole, bit by bit, this series of Welsh tributaries, and greatly shortened our imperial river. Then, again, it is possible that the ancient Thames received more water from the Midlands. Our English river-drainage system is very erratic at present, one of the least definite in the world; it may well have been far simpler in Eocene days.

Some hold that the ancient Thames once found its way out to sea at Harwich; then, later, at Maldon; and that its present course came after it had piled up Eocene silt all over Essex. Rivers before the dawn of civilisation easily changed their courses. It is civilised man, with his embankments and dredgings, who forces the river to stick to the course that suits him and his docks, ports, and towns. The prehistoric Thames was no doubt a wanderer.

Now a word as to certain physical and chemical properties of clay. Clay is a mixture of substances; the exact mixture varies in different places; but generally at least half of it consists of a material called "silica," a very important substance, because it forms one-half of the solid crust of the Globe. Nearly one-third of the clay is alumina (an oxide of aluminium), while only 5 per cent., or less, is iron. Aluminium is therefore much more common than iron, though it is dearer because far more difficult to extract. But how many dwellers in a clay district know that there is so much aluminium all around them? How many know that there is any at all?

The materials that make up the volcanic rocks, such as basalt (a hardened lava) and so forth, contain silica, alumina, and iron in much the same proportion. These ancient rocks are probably the same as the original solid crust of the Earth; and if so, all the later rocks are derived from them, torn up, consolidated, retorn up, again consolidated, again retorn up, again consolidated, and newly again retorn up, with much alteration of physical form, but little change of chemical elements. Clay and sand are both called "rocks"

by geologists, though not in ordinary speech. Sand differs from clay, physically, by having much larger grains; it contains an even larger proportion of silica. Silica is everywhere. It is a hard, glassy, colourless substance, the chief ingredient in glass. Our bricks, tiles, slates, window-glass, plates, dishes, firebricks, etc., all contain a large proportion of silica.

One very important quality is possessed by clay, owing to the fineness of its grains and the closeness with which they lie together. It is water-tight, or non-porous. It absorbs a small amount of water for a little way down, and then will take no more. That is why a clay field, after rain, offers such a greasy, slippery surface for us to walk upon.

What about the fossils of the London Clay?

Fossils are relics of past life: shells, bones, leaves, branches, footprints, or whatever survives to tell us the tale of ancient life. Taken on the whole, the Eocene is often rather empty of fossils; but there are places where the deposits are rich, and they tell us of a genial climate and an abundant life.

In the Isle of Sheppey we find remains of turtles and crocodiles, of birds and fishes; bones of tapir-like animals, ancestors of the very different creatures that live to-day. Tree-remains shows us palm, acacia, and mimosa; evidently a much warmer Thames-side than we know in this twentieth century.

Near Ewell, in Surrey, in the sands that lie under the clay, I have found an abundance of small sharks' teeth. How many people, when walking over such a sand, would look for sharks' teeth near London? Near Cheam, also in Surrey, Mr. Whitaker, the great authority on London geology, showed me a large bed of fossil oysters. There were, literally, thousands of them, closely packed together. These poor oysters had never graced a ceremonial banquet; they were no longer eatable, being much over a million years old; most of the shells were broken, but, in the mass, a most interesting sight. At Bracklesham, in Sussex, are Eocene sands with shell fossils of an almost tropical

character; and at Bournemouth are many fossils, especially plant-remains; these latter fossils suggest fresh water at this point.

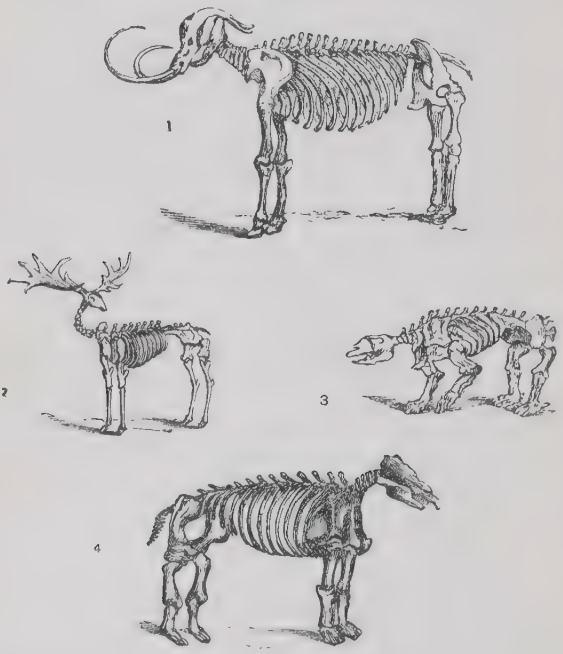
All these prove for the Eocene a long distance of time from our own day, though, as you will see later, there are many formations of vastly greater age than this. For, despite its remoteness, Eocene means "dawn of recent life," and lives up to its name.

It is believed by many that fossils would be far commoner in the Eocene if it were not for the presence of iron pyrites, by which name we mean a combination of iron and sulphur. It is a fairly common mineral; as a boy, I found it in plenty on the rocks on Eastbourne beach. It is usually of a yellow, glistening appearance; it forms that thin gold-coloured sheen that is seen in coal. The sulphur that it contains is very destructive. When we burn coal we release it, and its presence in the air of our cities destroys the face of our fine old stone buildings. When it is in the soil, the action of the sulphur will destroy shell fossils and unite with the lime that composed them to make glass-like crystals called "selenite." This I have often found in the Claygate soils near London. Those who do not know it might easily mistake it for glass. Sulphur and lime also combine to make gypsum, or plaster of Paris (called by chemists "calcium sulphate"); a handsome form is called alabaster.

In addition to the fossils of true Eocene age, bones are found in the London mud and gravel of creatures of a much later day. Not very long ago, when workmen were enlarging the drains near King's Cross, skeletons of a mother and baby mammoth were discovered. When the cellars of the office of the *Daily Chronicle* were deepened to hold a larger printing press, the skull of a woolly rhinoceros was found. And while foundations were being dug for Drummond's Bank, at Charing Cross, bones of an ancient type of man were discovered. These all lived long after the date of the Eocene, and were entombed in the gravels and surface mud of a later day. But they inspire the imagination

with wonderful pictures of the changes that must have been seen by Father Thames, if only that worthy had eyes to see and a tongue to tell the tale.

Imagine mammoth, rhinoceros, and hippopotamus all wallowing in the swamps of the Thames! Down some of the slopes, where now rolls the motor-bus, once



EXTINCT MAMMALS.

1, Mammoth (*Elephas primigenius*); 2, Irish Elk (*Cervus megaceros*); 3, Megatherium, South American Sloth; 4, Mastodon (*M. giganteus*).

great herds of heavy-footed beasts padded down the mud and beat out the irregularities. Great families of pachyderms represented London's first "steam-roller"; and, for anything that we can prove to the contrary, a horde of screaming monkeys may have met where the Houses of Parliament now stand!

These later gravels, in which such interesting fossils are found, are of special importance when we begin to connect London geology with London history. The early town-planners, here and elsewhere, avoided building on the clay because of the difficulty with the water-supply in a clay district, clay being non-porous, and cheap iron pipes being non-existent. Early London was built on the gravels and sands, cleverly avoiding the clays. The old London was London-on-the-Thames-gravel; it is the present London that is London-on-the-Thames-mud.

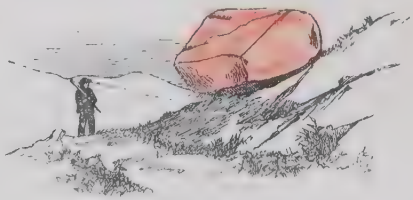
As already stated, the Eocene was a time of warmth, fertility, luxuriance. Many thousands of years passed; as time went on, the climate grew gradually colder and colder, till what is called "the Glacial Period" set in —a period when glaciers crept over Britain. The exact reason for this great cold, and the extent of it, and its general conditions, are still matters of much doubt among geologists. But certainly Britain was being lifted by Earth-forces higher and higher out of the sea; the North Sea became a large plain, joining us to the Continent; the Irish Sea was another plain, and land stretched many miles to the west of where Ireland now is, shutting off from us the warm Atlantic influences and the Gulf Stream. All this would be quite sufficient to lead to glaciers in Britain. There is no proof that these ever reached south of the Thames. They grew thinner and feebler as they crawled southwards, and probably melted at the foot of Hampstead Hill.

The main and higher part of Hampstead Heath is sandy. It is very interesting to stop and examine the little springs that feed the "Leg of Mutton" pond on the lower west heath. They come out of the ground where the sand meets the clay, because clay is water-tight; they are red with the fine rusty-iron grains that they are drawing from the sand; this is especially seen if you stir up the waters of the pond at the point where the springs enter. The pebbles at that end of the pond are becoming coated with red iron-rust.

The hills to the north of Hampstead are of quite

different formation. The Finchley ridge of hills, for instance, have on top a churned glacial boulder-clay—that is, a clay that has been ploughed by glacier action. Below this are gravel and sand; underneath these, again, is the true London Clay.

One well-known characteristic of glacier action is the power possessed by moving ice to carry great blocks of stone for enormous distances. Thus, a block of Norwegian porphyry was found half buried at Fortis Green, to the east of Finchley, not far out of London. Similar blocks have been found in a long line all down the East Coast; this is the most southerly of them all. Of all the natural forces known to us, only glacier action could have brought these blocks. Small patches of gravel are found on many of the hill-tops to the north



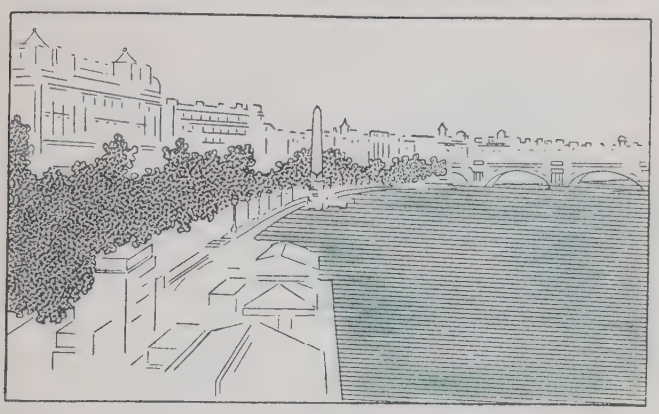
A Perched Block (Norway).

of Hampstead. The origin of these is still doubtful; it may well be glacial.

I happen to live on Temple Fortune Hill, north of Hampstead. Here there is, on top, 2 or 3 feet of curious, broken clay, that might very easily be glacial; then come 5 or 6 feet of rough gravel; below that is the real London Clay. In one or two banks cut for road-making the gravel section stands out. I was poking about in one of these banks, when I saw a strange-looking red edge, and dug out a piece of red sandstone which must have travelled over a hundred miles to get here, probably by glacier. It is a flat piece, rather smaller than a man's hand; it weighs just under a pound, and is astonishingly hard.

Let us try to sum up a few conclusions.

If you live in a clay district, it will be as well to try first to find out if the clay was river-borne or glacier-churned. If river-borne, try to find out why the river left it here, without carrying it farther; whether it was intercepted by a lake or by the sea. Next try to find out if there are any sandy stretches or gravelly patches. If these are above the clay, then look for springs where the sand meets the clay. Test the springs for iron. Note also that vegetation changes with changes of soil. On the clay we expect oaks and elms; on the sand, pine and birch. Sandy parts are often commons, because



LONDON: VICTORIA EMBANKMENT.

the land was not fertile enough for the farmer or landowner to cultivate. In gravels look for any piece of uncommon texture.

Lastly, seek for fossils, or at any rate try to know which fossils are to be found. Similar conditions will produce a similar clay, even if there are a million years' difference in age between the two. But the fossils may be quite different, in two very similar-looking clays. It is the fossils that tell the tale as to when the clay was formed; for Life has gone on in the ascending scale. The more advanced types of fossil life come with the

newer and newer rocks. It is often impossible to fix the period of a rock till its fossils are found.

* * * * *

Next time you cross one of the London bridges on the top of a motor-bus look well around you at the wide, flat plain on which London is built. Undeniable Thames mud!

CHAPTER II

THE CHALK—LONDON'S HILL GIRDLE

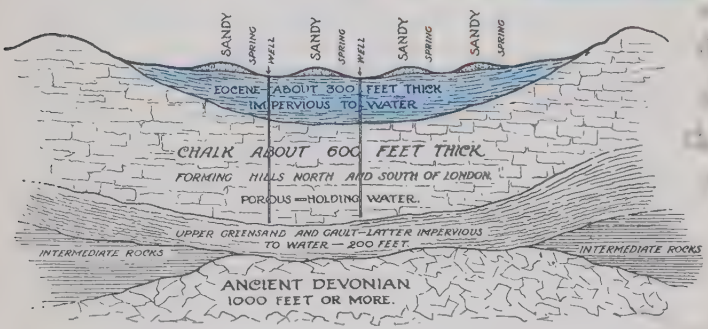
SEEING that the London Clay was laid down in the saucer-like hollow of a large lagoon, we must now consider what made the floor and sides of that lagoon; or, to put it another way, what is the rock that lies under the London Clay.

If we travel out of London either north, west, or south, within twenty miles we come upon low hills of Chalk. If we find the junction where the clay ends and the chalk begins, we can find out for ourselves that the clay lies on the chalk, the chalk emerges from under the clay. If we read up details of wells sunk in London, we find that they are driven right through the clay into the chalk. In a well bored near Golders Green the boring passed through 259 feet of London Clay, then through 64 feet of sand and pebbles (the "basement beds" of the clay), and then reached the chalk. All details of well-borings are of great importance to geologists.

Let us pause to ask why such wells, called "artesian" wells, yield a ceaseless supply of water. Clay is a rock through which water cannot penetrate. Chalk is a rock through which water penetrates easily. London is down in a saucer-shaped hollow, with chalk hills all around. Some of the rain that falls in the chalk districts will be held by the vegetation, some of it may

enter the few small rivers, but much of it will soak into the ground, and remain in the lower part of the chalk, like water in a sponge. Under the chalk there are rocks through which water cannot penetrate; so that quite a large supply is always trapped in the chalk, ready for the wells. Wells of this kind can always be made wherever the porous and non-porous rocks alternate; there are many of them in Australia.

Does any reader of this book live in a chalk district? He will realise that the water which his garden needs is too often escaping, perhaps to feed the Londoner's wells. He will know that among the wild-flowers



ROCKS UNDER LONDON.

special ones will exist which have learnt various devices with which to cope with the quick disappearance of water. Many of these have small leaves, or very hairy or downy leaves, which prevent them from losing too rapidly, in the sunshine, the water that they have been able to store up. The chief English forest tree that grows upon the chalk is the beech, which spreads out a whole tangle of roots near the surface, and so catches as much water as possible before it has time to disappear into the subsoil. Where chalk and clay meet, cherry orchards thrive. The stone needs the lime for its proper formation; and unless the stone is well formed, the fruit will be weak and liable to fall

before ripe. This is more for the botanist than the geologist, but these two branches of Nature-study help one another so much that he who is interested in the one should learn all he can of the other.

What is chalk? Chemically speaking, chalk is a soft limestone, and is chiefly calcium carbonate; but what is its geological story? Chalk is a rock that is formed very slowly under the sea. If looked at under the microscope, it is found to be made up out of uncountable numbers of tiny shells, so small that you could put a million of them into each finger of your glove, yet so beautiful in shape that you will hold your breath while looking at them, and think of the most delicately beautiful specimens of the jeweller's art. They have an almost endless variety of forms. They are made from carbonate of lime (which is dissolved, very thinly, in the sea-water) by minute jelly-like creatures for their shells. These wonderful little creatures are called "Foraminifera"; chalk is made up out of countless billions of their shells, that fell to the ocean floor as they died.

Does this mean, then, that all the chalk country that we see in England was once at the bottom of the sea? Certainly; this is proved beyond possible denial; and chalk is to-day being formed at the sea-bottom which Earth movements may some day make into land. I do not mean at the deepest depths of the great oceans, but neither do I mean at the shallow shore-line. At moderate depths was made all the chalk that we see in England, and far more besides. During the vast number of years that have passed since the chalk was slowly pressed upwards and made land, the effects of rain, frost, atmosphere, and of sea-waves beating against cliffs, have broken up and destroyed enormous quantities of chalk, as you will see later. But first I want to tell you that our English chalk is only a small part of the great field of European chalk, which covers 2,000,000 square miles; from Britain to the Crimea 2,000 miles, and from Sweden to France 1,000 miles—not exposed on the surface all the way, of course, but

formed and there, telling us of the days when the bulk of Europe was under the sea; when the Alps, now reaching up to 16,000 feet of height, were low parts of the Earth's crust, with sea-water lapping over them and fishes swimming over their crests—fishes, swimming above the Matterhorn and Mont Blanc!

English chalk now stretches, in an almost unbroken line, from the Isle of Wight to the middle of Yorkshire. Though we talk of "the white cliffs of Albion," it is only for a portion of this district that the chalk actually forms the cliffs; but when it does so, what a beautiful spectacle! I remember, right back in my boyhood, my thrill at first seeing the chalk cliffs of Kent—the rugged form and dazzling whiteness, the resplendence of it all in the summer sunshine; the fine contrast with the green sea and blue sky. Then the differences in height; the descent almost to the shore, and the ascent to the tall, bosomy downs; the evidence of past cliff-falls; the rocks; the feeling of a constant struggle between cliff and sea. There is a wonderful beauty in a coast that has a barrier of chalk.

Standing by a cliff, we are the better able to inspect the mass of the chalk, to realise it. Then we must certainly notice the flints that show so clearly, in contrast to the white background. These flints are made of that material that is called silica, of which I told you something in the last chapter. As half of the solid material of the crust of the Earth is made of silica, we are bound to keep on meeting it in various forms. The grains of silica that were dispersed in the sea where the chalk was formed had an attraction for one another, and got gradually together in little masses, forming the flints. Very often they formed where there was something to make what is called a "nucleus," or centre—that is to say, round a small sponge, or a piece of sponge; round a sea-urchin, or part of a sea-urchin; round a whole or broken shell. So that a flint is often to some extent a fossil, though among the enormous numbers of flints it is somewhat rare to find one definite enough in shape to prove its origin to any except a

trained observer. Occasionally one is lucky enough to find quite definite fossils in the flints.

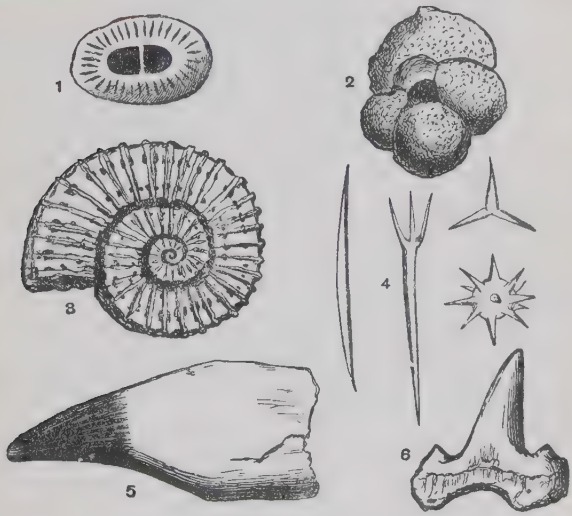
Flints are of all shapes and sizes, sometimes quite fantastic in appearance. An old rubble wall made of flints, each one the size of a man's head, carefully and strongly cemented together, is a really fine sight. The largest flints make good, bold rockery stones. They are of many colours. The reason for this is simple: silica itself is practically colourless, glassy, and partly transparent; it is the chief element in glass. Note how a flint breaks; see the glassiness of the surface exposed on the breaking, and the semi-transparency of it. A small mixture of colouring matter will colour the whole flint. Iron makes a good deal of the colour; under different conditions, iron may be either red or yellow, blue or green. The dull, blackish, slaty colours are vegetable stains; there is very often a blend of milk-white, the limy matter of the chalk.

Stand on a South Kentish beach and turn the flints over in your hands. How brilliant their colours are, when newly varnished by a film of sea-water and shining in the sun! Among the vast hoard of silica flints you will find, here and there, a quite alien rock—bits of granite, rolled smooth and very beautiful, that have travelled up the English Channel from Devon or Cornwall, having started on their trip probably centuries before your great-grandfather was born! Bits of felsite, greensand, and other rocks, but the greater part nothing but silica flints.

Where did they all come from, these millions of flints? That is soon answered. Imagine yourself standing on the chalk cliff of St. Margaret's, near Dover, on a perfectly clear day. Across the water, eighteen miles away, you will see the chalk cliffs of France. So small does the distance seem that I have more than once seen the spire of Calais Church and the hazy mass of roofs that indicates the town. Look down at the cliffs at your feet, see the clear traces of the devastations of the restless sea; even to a limited imagination it will be clear that once France's chalk cliffs were

joined to ours, and that the sea has steadily broken away eighteen miles of chalk.

Chalk is easily dissolved by the sea, but silica is not. Silica is one of our toughest rocks; we use it for our furnace linings. What would become of all the silica flints that were hidden in those eighteen miles of chalk that the sea has broken down? Those are the flints on the beach. I told you it was simple enough.



FOSSILS FROM THE CHALK.

1, Coccolith; 2, Globigerina; 3, Ammonite; 4, Sponge spicules; 5, Ichthyosaurus tooth; 6, Shark's tooth. (1, 2, 4, greatly magnified.)

Passing inland over the breezy chalk downs, let us notice the main features of the chalk country. For one thing, you will see trough-shaped valleys that will puzzle you at first. These valleys were once worn by water, like any other river valley. But more and more do the streams of the chalk country tend to find their way underground. These dry valleys, that were once watercourses, are the result. The Devil's Dyke, at

Brighton, is a grand example; but there are many others.

If there are woods on the chalk, they are certain to be beech-woods. If you see, in the distance, birch or fir, you will know that there the chalk has a covering of sand or gravel.

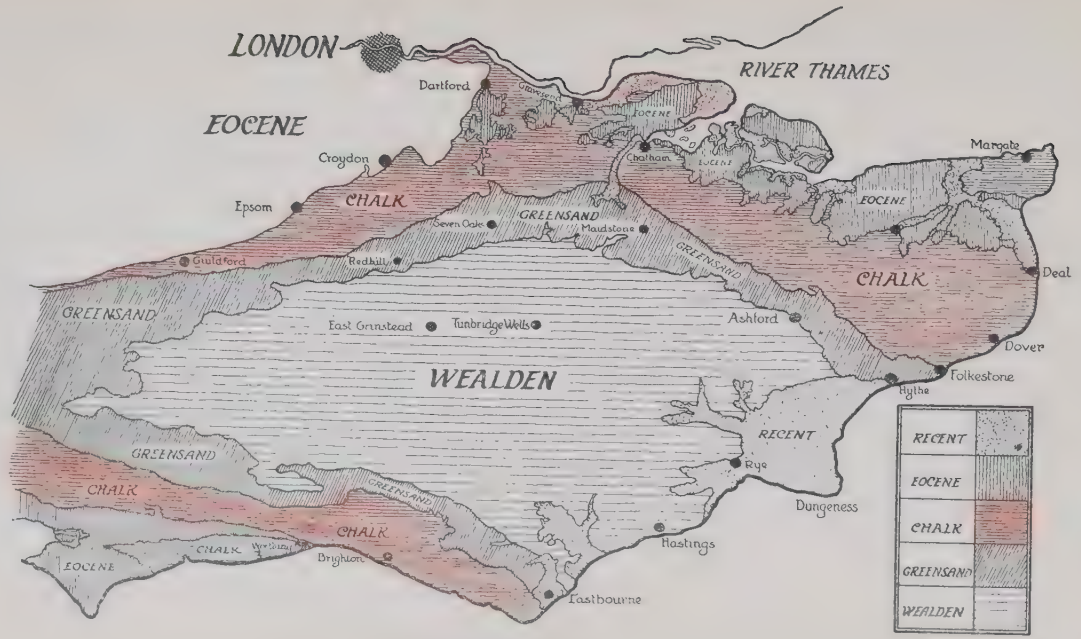
Fossils from the chalk include sea-urchins, good specimens being quite beautiful; long, pencil-like cuttle-fish bones, common; a variety of shells. I once gave a geological lecture to a charming school in the chalk country, but was told that no fossils were ever to be found there. I went with the children to the playground when the lecture was over, and began searching in a gravel-heap. In ten minutes we found about twenty fossils. Another school that I visited had a number of fine fossils, collected by an enthusiastic little boy aged five and a half only!

It will be seen that there is plenty of geological interest in a chalk district, plenty to examine and collect. But whatever type of district you may live in, remember to try to find the exact point where the formation changes to another type; that is always a source of renewed pleasure to the man who takes delight in observing and learning.

CHAPTER III

WEALDEN AND GREENSAND—SOME GENERAL PRINCIPLES

In Chapter I. we have discussed briefly the London Clay and the sands connected with it; in Chapter II. we have spoken of the great Chalk saucer in which these clays and sands lie. Now, to complete a little survey of the land around London, let us imagine ourselves taking a trip from London to the sea, travelling southwards, through Kent, Surrey, or Sussex, to Folkestone, Hastings, Eastbourne, or Brighton, noting the way we go and the land-formations over which we pass.



SURFACE ROCKS SOUTH OF LONDON.

We start in the belt of London Clay; we soon reach the chalk hills of the North Downs; we feel that we know something of all this, and are beginning to be satisfied with ourselves in consequence. But soon comes another change. Round about Sevenoaks, or Redhill, or the belt of land between, we come across a sandy-looking rock that has in it, sometimes more, sometimes less, a tinge of green. This colour is due to one form of iron, and the rock in question is called "Greensand," with two distinct beds, the "Upper" and the "Lower" Greensand. Between the Upper and the Lower Greensand is a greasy, sticky clay called the "Gault."

If we go on to Folkestone, we shall find all this beautifully laid out for us. On the western side, making the cliffs of the beautiful "Leas," is Lower Greensand, a splendid background to the plants that grow so freely here. On the eastern side, by what is called "the Warren," is Gault and Upper Greensand; this is a wonderful hunting-ground for fossils. A little way inland the Chalk rises quite plainly over the Upper Greensand, and gradually creeps nearer and nearer to the sea, the Greensand dipping away below it. Halfway towards Dover the cliffs are chalk. So that from a good view-point in Folkestone the junction between four formations is easily seen—Lower Greensand, Gault, Upper Greensand, Chalk. The fossils are chiefly sea-shells, and many of them are very handsome. Some are of the type called "Ammonites."

What have we learnt? That the Greensand was formed under the sea, and contains sea-shell fossils; that it was formed before the Chalk, as it lies underneath it. Sand consists of grains of older rocks, torn up by water action and dropped near a shore; chalk is formed in deeper water, where the rivers do not drop their sand, mud, and clay; so it seems clear that after the Greensands were laid on the shore-line the water deepened, allowing chalk to form.

An interesting light is thrown on this by the deep-well borings in London. We find that below the

Chalk the Lower Greensand is altogether missing, while the Upper Greensand is only very thin. That is to say, there was a ridge of older rocks, where London now is, when the Lower Greensand was laid down on the shore. But the land sank, and the site of London was under the sea when the Chalk was laid down; and it was under a huge lagoon when the London Clay was formed. (See illustration in last chapter, page 19.)

But we must retrace our steps a little; we are going on too quickly. I brought in the geology of Folkestone to make clear the question of the Greensand; let us now go back to our journey southwards out of London.

First the London Clay; then the Chalk of the North Downs; then the Greensand strip, by Redhill and Sevenoaks, by Maidstone and Ashford and south of Guildford. But after passing this strip, we come to another formation, called "the Wealden," which occupies much of Sussex and the western part of Kent, and which is very easily and fully explored in the neighbourhood of Tunbridge Wells. It can also be well seen in the bold sandstone cliffs that meet the sea on the east side of Hastings. "Wealden" consists of sandstones and clays, and is therefore similar to the Eocene of London and to the Greensand with its clayey gault. But there are also important differences. The fossils prove that the Wealden deposits were laid down in a huge freshwater lake; the Greensand was formed on the shore-line of a sea; the Eocene clays and sands were formed in a huge lagoon, partly fresh, partly salt.

If we collect all this evidence together, we find that the Wealden lake, which never covered the site of London, became slowly filled up with sands and clays, which even to-day are hundreds of feet thick; the land around slowly sank till the sea invaded the district. Greensand and clay were deposited; but the sinking still went on till the site of London was under water, and the enormous area of chalk, extending more than halfway across Europe, was laid down. The Weald was

no doubt a sandbank in the chalk sea, but it must have been covered with chalk, though less thickly than the surrounding portions. All these processes require an extreme amount of time; but as they so clearly happened, we must allow them the time they need, regardless of our astonishment. After this long submergence Europe began to rise, at what geologists call the beginning of "Tertiary time." The upheaval involved the bending of the land. It was not quick and violent, but long and slow. Britain felt the last waves of the extreme Earth-movements that began to make the Alps; for these huge mountains were also under the sea in the Chalk period.

The Earth-wrinklings were such that the site of London, which had stood above the shore of the Wealden lake and the Greensand sea, was now under water, a portion of a huge lagoon. Chalk lay all around it, and at the bottom of the lagoon; but while rivers slowly began to fill the lagoon with Eocene sands and clays, the chalk was being worn down, off the Wealden and off some of the Greensand. So that to-day, on a journey from London to the coast, instead of finding chalk all the way, we find exposed two of the formations that are under the chalk, and that once were covered by the chalk—that is to say, Greensand and Wealden.

It is now time for me to deal with a few general principles, things that I did not wish to deal with till we had handled the subject from a practical point of view; and in dealing with these principles that underlie all Geology, I must first answer questions that I know will occur to you, if you are new to the subject. You are certain, for instance, to say: "Up till now we have spoken of Eocene, and found that it was formed under water. We have spoken of Chalk, and found the same thing about it. We have spoken of Greensand and Wealden, which also were formed under water. It really looks as if all the land that we know to-day was once formed under the water."

Yes, that is so; it is one of the startling facts of

Geology, but it can be proved abundantly to be true; nearly the whole of the solid land of the world as we know it was formed under water; and of the small amount of immensely ancient rocks that we cannot prove ever to have been under water, even these may have been submerged so immeasurably long ago that all proof of this is lost. The most ancient part of Europe, the part that possibly has never been submerged, consists of the mountains of Scandinavia and Northern Scotland, with a small part of Ireland. You will see by the map that these are remains of one mountain chain, broken by extreme age, but amazing in its appeal to the imagination. These stood proudly on a continent that once extended right across where the Atlantic now rolls. These were ancient when the Alps and Himalayas were still under the sea; indeed, these could look on the Alps as an aged man a century old might survey a babe in his first year. So our first point is to maintain that nearly all our present lands were once under the sea.

Let us look at this question from another point of view.

The high land, the land standing out of the sea, is daily broken up by many forces. In the mountains the rate of destruction is most rapid; frozen by night and heated by day, the hardest rock-face becomes rotten, breaks into pieces, and falls in screes and avalanches. The weight of the great masses of snow helps to bring down the rocks, while glaciers are always tearing and ploughing their way along the valleys where other agents do not act so powerfully. Every year millions of tons of rock are falling from the world's mountain chains.

River and glacier action further break up and bring lower the fragments. Water, charged with destructive gases, dissolves the apparently massive limestones. Rivers come down charged with silt; and at the edge of the sea the waves make a constant fight against the cliffs. Were these forces never balanced by contrary forces, there is no doubt that, after millions of years,

they would reduce the whole surface of the world to flatness.

But Nature often works by two contrary forces (such as Night and Day, Winter and Summer, Activity and Rest, and so forth). And the opposite force to this constant planing down force is the force of upheaval from the wrinkling of the Earth's crust, due probably to internal shrinkage. This wrinkling, sometimes violent, sometimes slow and steady, produces mountains as surely as the levelling forces destroy them. Sooner or later the land under the sea, where the rivers have discharged for thousands of years thick loads of silt, hundreds of feet in depth, begin their rise. Then are formed new lands, made out of sands and sandstones and clays, where rivers have discharged their mud, probably near to an old shore-line, or made out of chalks and limestones if beyond the reach of river action.

This sort of thing has gone on over and over again in the world's history. Geologists, therefore, want some clear and certain way of distinguishing one kind of clay and sand from another kind, or one kind of limestone from another kind (chalk may best be regarded as a kind of limestone, newer and so less hardened than limestone proper). As two sets of clays or sandstones, if formed under similar circumstances, may resemble one another, even if one were formed a million years after the other, it is a good thing for Geology that there is a simple and satisfactory way of distinguishing between them, and that is by the fossils.

Fossils are relics of past life, whether shell, fish, worm-cast, leaf, twig, bone, or skeleton. And life has varied from time to time; has grown and developed in the wonderful scheme of Creation, that awe-inspiring secret of creative life that is so vast and still so hidden, despite the peeps behind the curtain of mystery that we are now enabled to make through the untiring research of learned men. So that when geologists speak of "Gault Clay," or "Kimmeridge Clay," or "London Clay," they are thinking partly of the position in

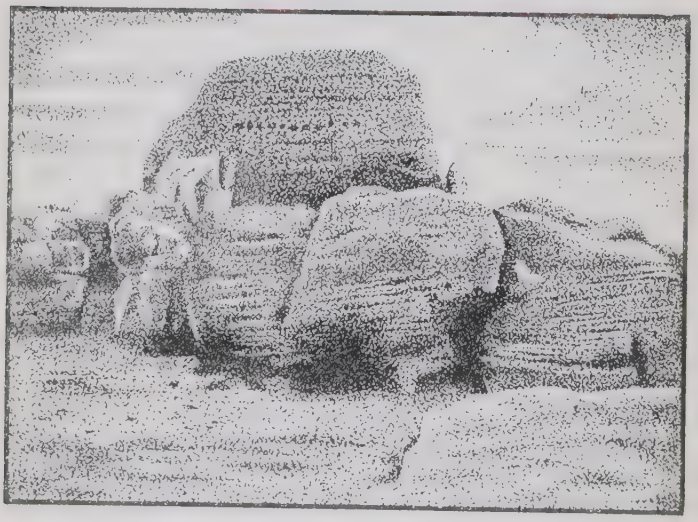
which these clays are found, and partly also, as a deciding feature in cases of doubt, of the particular type of fossil found in each of these clays.

Now we must consider another very important point —Geological Order. We have seen from our opening search that there is a definite order in our rocks. We have found, in our trial trip from London to the South Coast, that Wealden is under the Lower Greensand; above this Gault and Upper Greensand; then Chalk; then the Eocene sands and London Clay. We should now buy for ourselves the "Geological Map of the British Islands (based on the Government's Geological Survey); scale, 25 miles per inch." This map, clearly printed in colour, numbers the various rocks from No. 1 to No. 28, and shows us which rock *is found on top,* all over the British Isles. We find that Wealden is 22; Lower Greensand 23; Upper Greensand and Gault 24; Chalk 25; Eocene 26. The map can only show us the rock on top; it evidently cannot try to show us the rocks underneath. But we can find out something about these for ourselves.

We ought by this time to realise that under the rock numbered 22 we shall only find a rock of a lesser number—that is to say, an earlier rock. We may not find 21; it may be missing at this spot. The rock under 22 might be 18; but if so, 19, 20, and 21 will be missing altogether; neither of these three could be found under 18. And so we begin to understand geological order; the system by which rocks are classified is now becoming clear to us.

Let us take an actual example from London itself. At London we find on top the Eocene clays and sands, No. 26. Under that, as we have already seen, is Chalk, No. 25. Then a very thin layer of Upper Greensand, 24. Lower Greensand, 23, is seen at the edges *but not under the centre of London, where it is missing.* The beds below the centre of London *drop from 24 to 14.* This suggests *that the rocks of type* 14 (old red sandstone) *were sufficiently powerful, on the site where London now stands, to resist the stripping*

and lowering forces, and to stand out above the seas under which, during a very lengthy period, a very large series of rocks was being formed, not only in other parts of Britain, but all over Europe, and, indeed, in many other parts of the world. Of course, it is quite possible that Rocks 15, 16, and 17 may have been formed and destroyed; there would be plenty of time for this to occur. Rock 17 is Coal. (See illustration, p. 19.) *There is no coal under London.*



WEATHERED SANDSTONES, TUNBRIDGE WELLS.

As we are considering general principles, a very important thing to note is that this series of rocks, numbered on the map as from 1 to 28, *applies all over the world.* When Geology was first studied, not so very long ago, it was not known how universal was the application of certain facts that had been studied only in picked districts by enthusiastic pioneers. Hence there was invented a series of names that arose out of limited knowledge. Rocks first studied in

Devonshire were called "Devonian." We have since found these very rocks all over the world; and so we now talk of "Canadian Devonian," "German Devonian," "French Devonian," or even "London Devonian"; for Rock 14, Old Red Sandstone, underlying London, is a typical Devonian rock. It reminds me of the provision merchants who talk about "American Cheddar cheese"!

Thus, in the study of Geology, vast though it is, there are very welcome simplifying elements. We are dealing with different series of Clays, Sands, and Limestones; however perplexing may be the variety, there is an essential unity in the ever-returning circumstances that brought these about, and in the important fact that the processes of which we have evidence in the rocks of the past are processes which we can trace as proceeding in the present. And though we trace out changes so vast that they are staggering to our limited imaginations, yet we must realise that eternities are in question whenever we touch the mysteries of Geology and Astronomy.

River action and sea ooze, working grain by grain, have piled up rocks thousands of feet thick. We may be breathless at the thought of the immense time needed to achieve so vast a result, but we cannot deny the marvels thus made manifest. We must admit our own smallness by the side of the wonders of Creation. Again we realise the moment when "the Lord answered Job out of the whirlwind, and said: Where wast thou when I laid the foundations of the Earth? Declare, if thou hast understanding."

CHAPTER IV

LIMESTONES—THE CASE OF YORKSHIRE

If you look again at your Geological Map of Britain, you will see what is evidently an important formation, numbered 21 and called "Oolitic," stretching with barely an interruption from the southern coast of Dorset to the northern coast of Yorkshire. It consists of Limestones and Clays, the so-called "Portland" Limestone being a famous portion of it. This is well known as a building stone, and from it St. Paul's Cathedral is built.

Wherever the Limestone is well represented, it forms bold hills, so that the line of the Oolites is often called the "Oolitic Escarpment," *escarpment* being a grand name for a bold edge of rock. From the position of this Oolitic ridge it will be evident that it must be crossed by our chief lines of railway. The Southern Railway (old L. & S.W. main line) crosses it a few miles after leaving the Chalk hills of Salisbury and Wilton, just before Tisbury. The Great Western crosses it at Swindon, which is a geological junction as well as a railway junction; for here the Gault and Upper Greensand meet the Kimmeridge Clay and Portland (both Oolitic), with the Chalk only a few miles away. It is fine geological ground. The bold Portland Limestone is well exposed in the quarries, and the stones are simply chock-full of shell fossils Thousands could be got from the quarry, if one wanted such a lavish display. Beautiful ammonites, measuring a foot across, are sold by the quarrymen for a shilling each, and can be seen sticking out of the quarry cliffs. I have found corals and part of the backbone of the Plesiosaurus (one of the quaint old reptiles), as well as countless shells, both little and big. In the Kimmeridge I have found shells and fossil wood. In the Lower Greensand near by, which here happens to be a brilliant yellow, I have found beautiful fossil

sponges. The bulk of the Oolite is splendid hunting-ground.

In a strip of low-lying Gault is a beautiful wood. In April it is brilliant with primroses and anemones, with bluebells almost out. Dog's Mercury, not yet grown coarse, offers its bright varnished green under the oaks. The wood reaches a bold cliff of Upper Greensand, here of a pale whitish-green shade. The cliff is almost a precipice; but hazel-bushes climb it, and so

Oolitic Escarpment, Cotswold Hills.

do we (with an effort!). At the top are more primroses and some grand beeches. The view is splendid; in the near distance southwards, towards Marlborough, the rounded shapeliness of Chalk hills is unmistakable, and, to the north and north-east, in fine, wavy ridges, the Oolitic Escarpment.

From Swindon the escarpment only rises gradually. Its steep face is towards the west, which proves that from the westerly side came the force that sent it up; for every range of hills or mountains is steepest on the

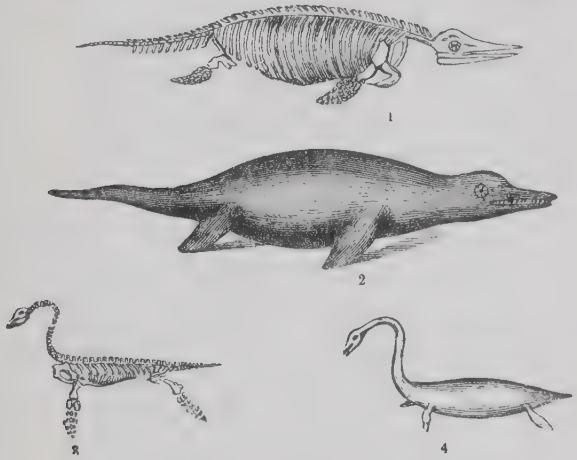
side from which the thrust came. Wherever the ridge is higher than usual it receives a definite name; for instance, it is known as the Blackdown Hills, Cotswold Hills, Edge Hill, Northampton Heights, and Cleveland Moors. As a rule, it forms a watershed, but the Bristol Avon cuts right through it in a pleasant gorge at Bath.

We can follow it from Dorset right up to Yorkshire; but a few miles after crossing the Humber it thins out rapidly, and for the moment it disappears, though a narrow ridge of slightly earlier rocks (Nos. 19 and 20, Lias and Trias) follow the same direction, and were evidently once covered by Oolites. Then we suddenly burst upon a magnificent mass of it, the Cleveland Moors, that make the coast from Filey through Scarborough and Whitby to Saltburn one of the wildest, grandest, and most romantic in England. Bold, massive Oolitic Limestones, weathering to fantastic and wonderful shapes, rising high above the sea, glittering in peaks and pinnacles amid the profusely rich, wild vegetation, broken by picturesque bays along the coast, yet stretching inland in a series of strong breezy moors, alive with a savage splendour of colour and untamed richness, magnetic, exhilarating, wonderful—the full, triumphant glory of our English Oolitic Limestones.

But while we are discussing Yorkshire, which is an excellent county for the study of Limestones, let us note that Yorkshire has been four times under the sea, coming up again after each submergence, to be submerged again in later ages. On our imaginary journey along the Oolitic Escarpment we cannot have failed to note that in South-East Yorkshire, from the Humber to Filey, there is a great mass of chalk, whose grandest viewpoint is the bold hill-cliff of Flamborough; Chalk, as we know, was formed under the sea. But Limestone is an ancient chalk, hardened by age and pressure, equally formed under the sea, and full of shell fossils and corals. So that the Oolitic Limestones of the Cleveland Moors represent an earlier submergence, long before the Chalk Age.

Passing south-west from Whitby, over the famous Vale of York, we note the fertile look of the soil: this is very recent land, marked 28 on our map; the Humber must have been much larger, a huge lagoon, up to comparatively recent times. The many rivers that meet in the Vale of York have brought down all this fertile land; we are not counting this in our list of the submergences of Yorkshire, for it is too local.

But still going westward, we come to the long,



REPTILES FROM THE OOLITES.

1, Skeleton of Ichthyosaurus; 2, restoration; 3, skeleton of Plesiosaurus; 4, restoration.

narrow strip of Magnesian Limestone that goes from Darlington to Doncaster, and which lies on the eastern flank of the Pennine Chain. This Limestone is of Permian age, so called after Perm, in Russia, where rocks of this period are well displayed. It represents a submergence far older than that of Oolitic times; it is numbered 18 where the Oolites are No. 21. It is a distinct formation of a different era. It dates back to very ancient times, when the great Pennine Hills were uplifted in a crisis that divided Britain finally

from America, and sunk a huge trough in the North Atlantic Ocean, which before had been land. On the eastern side of the newly uplifted Pennine range was the shore-line of the sea in which the Permian Limestones were laid down. Counting from modern times backwards, that is our third submergence of Yorkshire.

In southern Yorkshire the rich Coal-measures, consisting of thick seams of Coal divided by Sandstones, lie directly against, or underneath, this Magnesian Limestone. And of Coal, deeply interesting and important though it is, I do not intend to say much in this book, because, of all the facts known to Geology, those about Coal have been the most often written down. Surely we all know that Coal represents fossilised forests of pulpy, mushy trees that were more like gigantic mosses than the forest trees of to-day; that the little horsetail is the direct descendant of one sort of Coal-tree, and once grew as large as our present oaks; that all this vegetation, grown by the power of the sun, sank or drifted into sandy swamps, where it was speedily covered and preserved from decay; that to-day we draw from the Coal the heat of the sun of millions of years ago; while in certain drugs made from Coal we draw the healing powers of the sun of millions of years ago; and in certain dyes made from Coal the colour-effects of the light of the sun of millions of years ago.

Let us pass, then, right over the Coal-measures, right over the Millstone Grits, which we leave for our next chapter; let us trace our way to the grand mountain Limestones of North-West Yorkshire, where these superb masses make the great sprawling bulk of the Pennine Chain. These are No. 15 on our map, and mark the fourth submergence, reckoning from the Chalk backwards, of our county of Yorkshire. This submergence was infinitely earlier than that which caused the Magnesian Limestone, for it was long before there was any Pennine Chain at all, or any Coal. These handsome, glittering, solid Limestones, so full of shell fossils that you can reckon to pick a few toler-

able specimens out of every heap of road-repairing material in the district, and often containing interesting corals, reach, in places, a thickness of 4,000 feet. This represents an agelong submergence. They are usually of a bright dove-grey colour, but in places become quite a blue; they are brilliant and sparkling; they form grand cliffs and magnificent gorges; though the rock is tough, water charged with acid fairly easily wears away the softer portions, and forms the most fascinating and mysterious caverns. All these facts unite to make the Limestone mountains of the Pennines a most delightful district to the lover of bold, wild scenery, who is not beyond the exertion of a good walk or scramble.

The Limestone caverns of the Pennines are perhaps best seen in the Peak District of Derbyshire, where there are many splendid examples, especially round Castleton. According as the rock is hard or soft, the passage narrows to a stooping hole or widens and heightens to a superb hall. The underground stream that has done all the work prattles by our side, as, accompanied by guide and candles, we peer our way through the cave of mystery. A fine adventure, surely. At Castleton, too, is shown that wonderful form of fluorspar known to the local miners as "Blue John," a rock of extreme beauty. The *Blue John Shop* is a sight that must not be missed.

But one of the greatest wonders of all our Limestone series is on the side of Ingleborough, that noble Pennine giant. Limestone mountains lie all around it; on every hillside are those typical Limestone blocks, of rough, irregular shape, by which, even in uncoloured photographs, Limestone formations can at once be detected. (For instance, when I first saw lantern pictures of Thibet I knew at once that the rock shown was Limestone, though I had not been previously told. Imagine a Limestone, formed under the sea, and now forming a great block of country with an average height of 16,000 feet!) Granite blocks weather even more sharply and irregularly than Lime-

stone; but Sandstones and Millstone Grit weather in more geometrical form, more like cubes with rounded edges. It is useful to note the peculiar weathering of each different rock. (See illustration, p. 32.)

The upper rocks of Ingleborough are quite different from the lower. The rocks on the flanks are Limestone, but the dark, grim cubes of rock at and near the summit are of Millstone Grit. There is a fine cave in the lower part of the mountain; but the finest sight of all is "Gaping Ghyll." This is a deep hole in the Limestone, halfway down the slope. Into this hole, which is 365 feet deep, there rushes, in wet weather, a roaring torrent, a real river, though it dries up in a long spell of fine weather. Go after heavy rains, lie flat, and lean as far as you dare over the edge; see and hear the rushing, sparkling torrent dashing with thunderous roar into that darksome, echoing hole; you will never forget it.

On fine, dry days, geologists have descended with ropes. At a depth of 365 feet there is a large natural chamber, with solid floor. The water escapes through a number of small holes and channels, it having reached an extra hard layer, which for the moment seems to be defying its action. Finally the water seems to emerge in a series of separate springs.

On my first visit to Ingleborough, I came to the mountain from the Ingleton side, but sent my luggage on to Clapham (the Yorkshire Clapham; no possible resemblance to the London Clapham!). The day was threatening, but I made the ascent. As soon as I arrived at the top, a blinding, soaking mist came round me and on me and through me, all at once. I began the descent, on the Clapham side, in groping darkness, and I knew that on my path down lay this awful chasm, 365 feet deep!

Wet limestone is slippery stuff; every little slide that I made I fancied myself on the way to the bottom of Gaping Ghyll! Where I passed the monstrous mouth I do not know; I came to Clapham safely, and visited the Ghyll the following morning. A wonder-

ful place; but not the sort of hole that one wants to slide down in a blinding mist. Even a determined suicide might shudder at that grim prospect!

A marked feature of Limestone districts is the dry valley or disappearing river, caused, of course, by the porous nature of the rock. Follow down such a stream as the Derbyshire Lathkill; suddenly the river disappears, the valley is dry. Seek for the cause; you

SURFACE ROCKS OF YORKSHIRE.

will soon find the "swallow-holes" down which the stream is plunging. Lower down the valley it emerges again. This may occur often in Limestone or Chalk country; and as the years go on, the streams tend to hide more and more as they work upon their valleys.

Our chapter on Limestone would not be complete without a word upon Marble. Our various beautiful Marbles are for the most part Limestones that have been baked by internal heat of the Earth, or by near-

ness to a volcano vent, which comes to the same thing. (But the word "marble" is sometimes used, rather carelessly, for any fine stone that will take a high polish.) And as Limestone is, of all rocks, the one with the most fossils in it, it will at once occur to you that Marbles may and often do contain fossils—far more often than the public has any idea of.

Look carefully at your marble-topped washstand, at the marble counter of your baker's shop, at the marble-topped table at your restaurant; you will probably find fossils in it. In the London restaurants the marble used is often a Belgian-Devonian-Red-Limestone-Marble, and is full of fossils, generally either shells or corals. In the central restaurant at Hitchin Station the mantelpiece is full of fossils. When I was taking a light meal there, I pointed them out to a gentleman who happened to be by my side, a perfect stranger to me—a commercial traveller, I think. When I showed him the fossils, he said: "Why did they put them there?"

I explained that no one had put them there, but that they had lived and died in the ordinary way, and left their shells in the limy sea-bottom, which had, after long ages, hardened and baked. He then asked: "How long ago did they live?"

I hazarded a reply: "No one knows exactly; but say ten or twenty million years ago." He looked quite startled, seized his bag, and ran out of the room! I never quite understood what frightened him—whether it was the weight of all those years, or whether he thought that he was talking to a dangerous madman. . . . Settle it how you please, but certainly he ran!

I was once changing some money in a Swiss bank, and stopped to point out to the elderly cashier the fossils in the marble counter. He looked with some interest, remarking that he had never noticed them before. "But how long have you been in this bank?" I asked. "Twenty-five years." And I had been there twenty-five seconds when I saw those fossils!

The marbles at Keble College, Oxford, up the stair and in the Great Hall, have very fine fossils, corals, and shells. There are some in the marbles at St. Albans Cathedral. But every real marble should be looked at; they are so often fossiliferous, and so very interesting. The marbles at the lavatory at the

Actual Tracing from Top of Marble Table.

Elephant and Castle, London, are very fine—indeed, wonderful.

When I was going over the Palace at Salzburg, I noticed that the red marble pillars were fossilised corals. I was told that they came from the Untersberg Mountain. They were most beautiful and interesting. Recall the history of them. Begin by picturing them as corals growing in the sea, dazzling white. Them-

selves of lime, they are slowly choked with limy sea-ooze, and more and more of such matter is piled steadily above them, till pressure makes of the whole one semi-solid rock. Yet the whiter form of the corals would still stand out, if only we could see down into the bulk. Upward pressure takes place, upward squeezing, firm but slow. And at some time into the whole mass runs water charged with rusty iron, that turns it all red; only the coral, being firmer than the rest, is of a paler red than the main body. And now heat bakes and glassifies it. The final compression and consolidation takes place under great heat. Have you not seen two bars of metal in the blacksmith's forge merge together and become one by the joint action of heat and pressure? Beautiful red marble, with all the coral markings a paler red, and still showing perfect form, is hacked by the quarryman from the red heart of the mountain quarry. And in the Archbishop's Palace, these red marble pillars.

The Archbishop preaches a sermon on the Eternities. . . . And how long ago, Right Reverend Archbishop, were those marble pillars of yours living corals in the pre-European sea?

CHAPTER V

MILLSTONE GRIT

THAT bold series of rocks, known as the Millstone Grit, and numbered 16 on our map, appears almost entirely in our Pennine Chain, chiefly on the east side of it, and largely in Derbyshire and Yorkshire, with a little representation in Durham and Lancashire. These are coarse, gritty sandstones, making splendid grindstones, good building-stone, and picturesque rocks from the scenic point of view. Durham Cathedral is built of a close-grained Pennine Millstone Grit, and stands on a bold rock of later Sandstone. It was built

800 years ago; but the massive stone is still in a fine state of preservation.

But the Millstone Grit has one disadvantage: its gritty face makes it an easy lodging-place for dust and dirt; so that when it is exposed for a length of time, either in the form of rocks or of building-stone, it is apt to lose its beautiful colour and become dull and grimy in tone; this gives to some of its escarpments a heavy, gloomy, dirty-brown look, which, however, has a grim force of its own, especially when relieved by bright-coloured vegetation. When newly quarried it is a truly lovely stone—a rich, fawny golden-brown, shading to strong reds or paling to a silver sand, sparkling with bold grains of quartz, and sometimes containing pebbles as large as hazel-nuts; for different varieties vary greatly in fineness. Some are made up of large, glistening pebbles; these coarser grits have immense beauty and character.

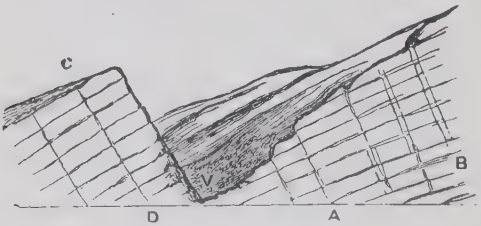
In all "sedimentary" rocks, rocks laid down grain by grain, by water action, there are long visible lines of division running cross-wise and called "lines of stratification." These mark some point in the process where there was a stop and a new beginning. They are of supreme value to the quarryman and the builder, enabling the former to get straight edges on his stones for the use of the latter. One peculiarity of the Millstone Grits is the exceptionally long distance between the lines of stratification. I have seen 30 feet often. Compare the Derbyshire Millstone Grits with the Permian Sandstones near Sheffield, and you will at once see the striking difference between the distance of the stratifications. In the latter 3 or 4 feet, or often less.

This enables the Derbyshire quarries to produce exceptionally large and heavy grindstones. Some of these are used for paper-pulping; and there is a regular export of these heavy stones from Derbyshire to America, as in all America there is not to be found so good a natural grindstone as this.

All lines of stratification were horizontal when the

rock was laid down. It is interesting to note the angle by which these lines now slope towards the horizontal. This angle is called the "dip," and the rocks are said to "strike" in a direction at right angles to their dip. The Millstone Grits of the Peak District, forming low mountains, 1,500 to 2,000 feet high, show stratification dipping towards the east, the strike being north and south. And we find that, a few miles to the eastward, these Grits have dipped right underground, and are found *underlying* the Coal. Miners call it "the Farewell Rock"—farewell to any hopes of coal lower down.

It may seem a little strange that a rock that is on the top of low mountains in Derbyshire is under the



VALLEY OF EROSION.

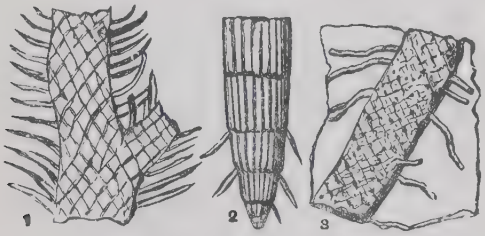
A, B, Stratification; C, D, joints. Joints are lines at right angles to the strata.

ground in Yorkshire, five or six miles away; but if you note the angle of dip and work out the distance, you will find that the fall needed to produce this effect is not such a very great one; 1,500 feet in 5 miles is 300 feet in 5,200, or say 1 in 17; but as the Grit goes underground at a point higher than sea-level, the actual dip is more like 1 in 25.

If you go to one of the quarries in the Millstone Grit, ask to look at fossils, which quarrymen often keep for the benefit of visitors. You will be shown highly interesting ones, which preserve very wonderfully the bark-markings of the old trees that made the coal. There is no wood, coal, or carbon in these fossils. This has all rotted away. But as it slowly rotted, ages

and ages ago, into its place ran grains of sand, and these have exactly preserved the old markings, the very quaint and beautiful markings of the various barks. Gigantic horsetails and huge tree-mosses are here, with bark of the most lovely patterns.

When I lived in the Peak District I had many fine fossils. I had a fine tree-trunk, that a friend once guessed to be the leg-bone of a mammoth. Only a little mistake of twenty or thirty million years! But what I treasured even more was a piece covered with ripple-marks—the exact kind of marks that the tide now makes when it leaves the sandy shore. Think of it! These Sandstones were sands on the old shore of the Carboniferous Limestone sea millions of years ago.



COAL-MEASURE PLANTS.

1, Lepidodendron; 2, Calamite; 3, Stigmaria (a root).

As they gradually rose, from steady pressure beneath, there came a day when the tide rolled over them for the last time. The ripple-marks made by that tide were gently covered, perhaps by blown sand, and though millions of years have passed, those ripple-marks remain. "Sermons in stones" are talked of by our Shakespeare. I know of no sermon more eloquent than this—that there should be such permanence in a thing apparently so trifling. Is anything ever a trifle? That ripple-pattern in the Sandstone remains to me as one of the most wonderful things that I have ever seen.

To the west of the Millstone Grits, still in the Pennine Chain, are the Carboniferous Limestones (that is to say, the Limestones that are connected in

our minds with the Coal), numbered 15 on our map, and of which I spoke in our last chapter. They are below the Millstone Grit; we saw that they formed the base of Ingleborough, with Millstone Grit on the top. But to some extent the two may have existed side by side, as a sea-formation and a beach-formation. Both are exceedingly massive; the Limestone in Derbyshire is 4,000 feet thick. Imagine the vast slice of time for such a mass to accumulate in the sea!

Kinderscout, in Derbyshire, is a great Millstone Grit mass, 2,000 feet high, part of a huge table-land measuring about eight miles by eight, or sixty-four square miles. This is one of the wildest districts in England, savagely splendid to the last degree. I have

ROCKS UNDER THE PEAK DISTRICT.

walked there all day, hardly meeting a soul. It is covered with bogs, and is very liable to winter mountain mists; this makes it so dangerous that two persons died there, lost, in the winter of 1922.

I and a friend had a glorious winter ramble there on one occasion. It rained, snowed, and hailed till the peaks of our caps were ornamented with icicles. The peaty ground oozed water, and we were often in it over our ankles. Then the mist came down on us suddenly, and we could not see our hands before our faces. Luckily I had a compass, and so could steer a straight course. I warned my friend against bogs, and he asked me what he should do if he felt himself sinking rapidly into one. "Throw me your purse," I answered, "because it would probably be of no further

use to you." After that he let me go first. We arrived at our destination wet through, as hungry as hunters, and both declaring that we had never had a jollier day in our lives. I now understand why, despite a long spell of dry weather, the River Derwent never dries wholly up. Those spongy peat-bogs on top of Kinder hold back an immense reserve of water, which only escapes slowly. Before that reserve could be exhausted, more rain would come.

If we follow the Upper Derwent down from the savage grandeur of Kinder, it is both beautiful and interesting. On the hill-tops, great ramparts of Millstone Grit; nowhere could we see it better. Owing to its tendency to weather in cube-like blocks, some of its rock-stacks look like the buildings of giants. Wind and weather have worn it, on the flat places of Kinder, to a sharp, glistening silver sand. But as we follow lower, lower, we come to a belt of a tenderer, softer beauty. Delightful streams, rushing and prattling, run between great boulders of rock. In flood-time, huge rocks of 20 tons and more, undermined by the current, have been known to roll suddenly some yards downstream before they pitch into a place where they jam and rest. And sometimes the stream runs, for 20 yards or more, underground, having worn away the softer sands or clays from under the huge boulders.

Woods begin to appear, and soften still more the beauty of the scene. On the sandier stretches we get birch very plentifully, and sometimes beech, where not too sandy. By the waterside we get alder. Everywhere we see beautiful wild-flowers. As we go lower we come to a belt of stiff clay. This is glacial clay; great ice-ploughs rolled it into the valley. It is full of massive sandstone boulders that have been ground into it by that irresistible force. The noses of these boulders often stick out of the soil, but often they are completely hidden. Then, when a builder is digging the foundations of a house, he will find, a foot under the clay, a huge block as big as a dining-table, crushed in and smothered over by the glaciers of long ago.

The builder will be glad, for on such a rock he can build any house. But the farmer finds it a fearsome land to plough.

We have followed all too briefly the varying fortunes of the Millstone Grit; and if every letter of every word in this chapter stood for a thousand years, that would be less time than has passed from the formation of the Grit till to-day; and yet it is only No. 16 in our series. We have seen the Grit grow, as a sand deposited on an ancient beach, beside the Carboniferous sea; we have seen, with a great thrill, the very ripple-marks of that sea; we have seen the bark-markings of the old Coal-trees. We know that the sands hardened to sandstones, and were pressed slowly up into mountains; at this same time the Atlantic was sinking, and Britain was being divided from America. And these great mountains were ancient when Alps and Himalayas were as yet unborn!

Long ages passed, with vast changes; and the Pennine Range was gradually torn lower and lower by the forces always working to destroy mountains; many a mile of "newer" rocks was formed from pieces torn away from these heights, till to-day there only remain the stumps of the ancient mounts—great, sprawling tablelands that (you can see for yourselves) are, and can only be, the worn stumps of once far higher heights; worn, ancient stumps, but still wild, still grand, still adventurous. And down them, in what are to the geologist comparatively recent times, crawled the glaciers, the great ice-ploughs that ground the soil beneath them to mud, that tore rocks from the hillsides and pounded them into the clay, that put the last touches to the shaping of these valleys, and then melted away.

And the result of all this long series of rock adventures? The glorious Peakland, wildly beautiful, stern in its heights and smiling in its valleys—a playground, a beauty-spot, an inspiration.

CHAPTER VI

DEVONIAN ROCKS

DEVON, beautiful Devon, is famous all over the world for its scenery—famous for that wonderful charm, variety, richness, softness, grandeur, and enchantment that merge together in her lovely territory, and which are added to by the soft music of the Devon speech, the courtesy of the Devon men and women, the sweet old-world glamour of the Devon villages. There is no lovelier or more romantic coast-line in the world than that which runs from Morte Point, west of Ilfracombe, through Combemartin, Trentishoe, Lynton, Lynmouth, and Porlock, to the quaintly picturesque bay of Minehead, embracing the north coast of Devon, the wild grandeur of Exmoor, and entering North-West Somerset.

Enough has been said already of the connexion between Geology and scenery to convince every reader that if Devon is so lovely, much of this must be owing to the Devon rocks. True, indeed. Devon was early a centre of geological study, and the magnificent rocks of her north and south coast were promptly christened "Devonian"; and though, as earlier chapters tell you, we have since found "Devonian" rocks in Wales, in Ireland, in Scotland, in America, in France, in Germany, and, indeed, all over the world, including a fine buried ridge of them under the chalk that underlies London, yet the name "Devonian" still applies. In Devon these rocks are imperial; they dominate the county; they fascinate the onlooker; they fight their strong and gallant fight against the restless sea. The Devonian rocks embody the very soul of Devon, with all its beauty and all its strength.

They are wonderful in colour. It is easy to talk of them as "Red Sandstones and Red Limestones," but that gives little idea of their richly varied hues, as they rise, perhaps in sheer cliffs a thousand and more feet,

right out of the sea, varying in shade from the warmest red to the richest purple, ornamented with white bands of sparkling Quartz, and offering the most marvellously toned background to the luscious greens and the multicoloured flower-tints of Devon's profuse botany. Often and often geologising along Devon's shore, I have cried out aloud in sheer admiration of Devon's supreme colour-riot. And then the shapes of these bold rocks, these noble cliffs, these wonderful and innumerable bays into which the Devon coast is broken, each little bay more picturesque than the last. . . .

Let us establish a few connexions between the scenery and the geology of Devon.

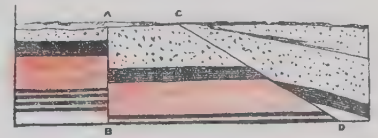
In the first place, the rock is a very old one; it is numbered 14 on our map. We began with London, comparatively new, No. 26, and we have worked steadily backwards to 14, a rock of immense age. It has gone through enormous pressure, which has hardened it; some of the softer layers have been bent into wavy lines under the strain. In numberless places we find "slickensides," which means that the rock is absolutely polished, by strong scrubbing against another rock surface, now fallen, in times of great Earth-disturbance. This also shows itself in what is called "slaty cleavage."

Hold a book so that each hand presses against one of the covers. Exert a little sideway pressure in opposite directions. The fact that the book is divided into pages, that give as you press, enables you to do this easily. If great sideway pressure is exerted on rocks, they tend to cleave or split in the required direction that enables the rock to bear the strain without smashing to pieces—that is to say, the rock cleaves into pages, like a book. This is called "slaty cleavage," because slates are simply immensely ancient, discoloured clays, that have undergone just this kind of pressure. Slaty cleavage occurs in many of the much-tried, much-contorted rocks of Devon.

Another marked feature of these rocks is the "faulting." To geologists, a "fault" means that a certain

part of the rock has slipped down during Earth-movements. Faults can be easily proved; a certain band of rock apparently ceases to be continuous, but careful looking shows that it continues a few feet too high or too low. Look at these figures:

6	4	.	5	4
5	3	6	4	3
4	2	5	3	2
3	1	4	2	1
2	.	3	1	.
1	.	2	.	.



FAULTS. (ALONG A, B, AND C, D.)

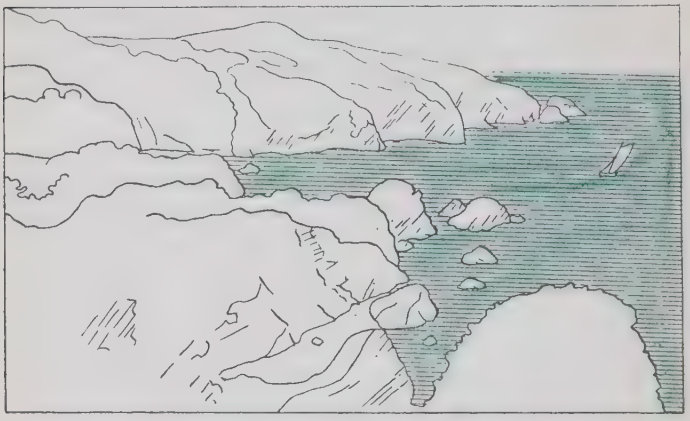
Supposing that I told you that the sixes had once all been in the same straight line, and the same with the fives, fours, threes, twos, and ones? You could soon find out exactly how far each vertical row had slipped. The same with faulting. But what is very important when applied to scenery is that the fault is always a line of weakness; in Devon, with its plentiful rainfall, little streams burst their way down faulted valleys; and on the coast the sea tides force their way in where the fault has broken the resistance of the rocks. These wonderful little bays that make the Devon coast such a line of beautiful surprises are "faulted" bays; so that in Geology even the faults become virtues!

Closely connected with the grand wildness of Devon are the many evidences of volcanic disturbance. This part of Geology will be dealt with later; we merely mention here the bold mass of Dartmoor Granite that dominates the inland views, and the outcrops of Felsite and other fire-formed rocks that tell the tale of Volcanic and Plutonic disturbance. Geologically speaking, Devon has had a stormy history; it has the rugged beauty that goes with those who have been many times tried by fire and shock, but who still smile bravely in the face of God's beautiful sky.

Dr. Evans, of the Imperial Institute, himself a brilliant geologist as well as a most courteous and helpful

expounder, has studied the Devonian with an especial enthusiasm. It will be interesting to note what he says about the general conditions:

"During the Devonian period, the coast-line between the land on the north and the sea on the south seems to have repeatedly shifted its position. . . . The surface seems to have slanted gently and continuously downward from the foot of a mountain region in Wales, southward to what is now the English Channel. To the north was an area where desert conditions prevailed, varied only by rivers that flowed after heavy



DEVON COAST AT COMBE MARTIN.

rainfall, and by sheets of water that dried up in times of drought. In those days, when vegetation appears to have been still, at least, semi-aquatic, and to have required an ample supply of moisture in the form of standing water or marshy ground through the whole or a great part of the year, desert conditions were *consistent with ample rainfall,* for wherever there is no vegetation to protect the surface from the action of sun and frost and wind, a desert will come into existence.

"Three times, during the Devonian period, the waters of the ocean retired to the southward, and three

times they advanced again and recovered much of the lost ground. At the beginning of the Devonian period the sea lay to the southward, and in South Devon and South Cornwall the water in which the materials of the Dartmouth slates were laid down was, at times, sufficiently salt for a few marine organisms to exist. . . . Subsequently the shore-line shifted to the northward till it lay somewhere in the region that is now the Bristol Channel. It then retired southward, and continental conditions are evidenced in North Devon by the Hangman Grits; but the south of the country still remained under the sea. Upper-Middle-Devonian time was marked by an important and nearly world-wide advance of the sea, but once again there is no evidence that it ever extended to South Wales, though it is impossible to make any definite assertion. Once more, in Later Upper-Devonian time, the sea retreated southward and continental conditions prevailed in North Devon, but the deposits laid down in Cornwall and South Devon were still marine, though they show evidence of the probable neighbourhood of a desert-land area. The closing days of the Devonian period and the beginning of the Carboniferous were marked by a recurrence of marine conditions, not only in North Devon, but also in Western South Wales and Ireland.

"All these changes were of a comparatively slow and peaceful character . . . but at, or towards, the close of the Carboniferous period a crustal storm of the greatest violence affected the area which is now the South-West of England. A powerful thrust from the south urged a solid mass of ancient rocks against the low-lying and still unconsolidated Devonian and Carboniferous sediments to the north, crumpling them into innumerable folds. . . . An indirect result of this great thrust was the intrusion of the granite masses."

Those who may find these details almost too bewildering will, at any rate, realise that Devonian geology is a somewhat complicated study, even for the expert. When they next look upon the majestically beautiful and multicoloured rocks of lovely Devon, they will

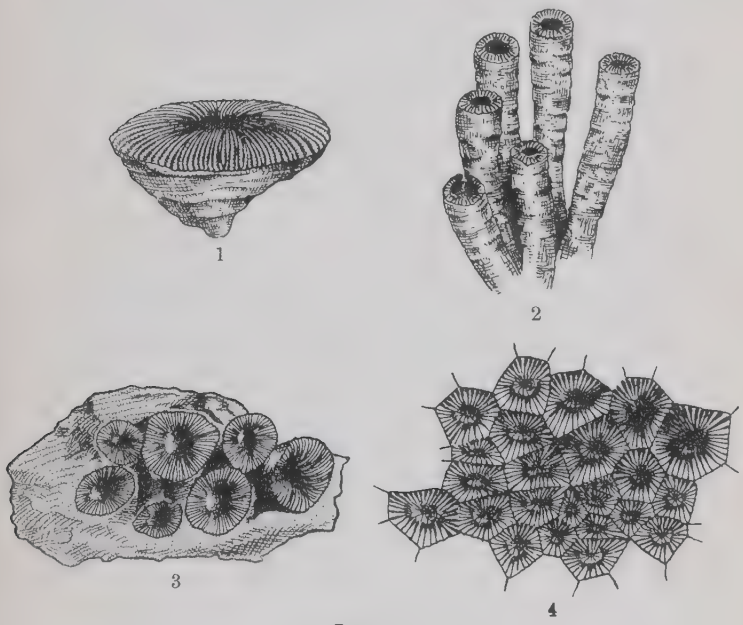
realise with some thrill that the story behind those majestic stones is as wonderful as their shape, colour, and beauty might lead us to expect.

Now a word as to Devon fossils. The most interesting fossils that I myself have found in North Devon have been the corals. Here let me give my reader a word of warning. Devonian rocks are often referred to as "Old Red Sandstone," and the Geological Map of the British Isles, to which I so often refer, calls them by this name. But in reality they are very varied in texture, and many of them are *Red Limestones,* while the colour varies from purple to grey. You know from past chapters that fossil coral makes Limestone, and the corals to which I have just referred are, of course, among the Limestones of the Devonian. Near Combe Martin beach there is a great rock as large as a cottage that is entirely fossil coral; chip it with your hammer where you please, a piece of coral will split off. In Combe Martin Post Office a block of fossil coral as large as a footstool held open the door when last I was there.

Shells are not uncommon, but generally so welded into the rock that extraction is impossible. Fish-scales and plant-remains are to be found. In the Devonian of Scotland (at Dura, in Fife) a wonderful mass of fish-remains has been explored, and perfect specimens have been secured. In the American Devonian beds the most ancient known remains of insects have been found. On the whole, in Devon, the Red Limestone yields far more fossils than the Red Sandstones and Grits. That is true of Limestones in general.

In addition to the fossils, rock specimens are worth collecting: pieces chosen for colour or to illustrate slickensides. And as there is mineral wealth in Devon, from the scrap-heaps of the mines many a sparkling and interesting piece can be picked up. The North Devon ore is usually a combination of lead, silver, and zinc, and is very handsome. It was once whispered that a small vein of gold had been found in Devon; but that was by a Scotsman!

A fine-grained red sandstone makes a beautiful building-stone, warm-looking and rich in tone. After a shower of rain the colour comes out very strongly, especially if the sun begins to shine. This stone is used largely in building blocks of flats in some of the pleasanter suburbs of Glasgow, and makes these parts of the city very pleasing to the eye. But the effect is



CORALS.

1, Simple coral; 2, finger-like group; 3, loosely grouped; 4, very sociable!

still finer in quaint, old-fashioned little towns, such as Kirriemuir, Barrie's town, which he has called "Thrums." It is twenty-five years since I passed through Kirriemuir, but I still remember the warmth of its red stones and the romance of its colour.

Devon and the Devonian! These are symbols of beauty, wheresoever found.

CHAPTER VII

WALES AND SCOTLAND—THE CURTAIN AND THE MYSTERY

I DO not here wish to say much about the scenery either of Wales or of Scotland. They are famous all over the world; their beauty, like that of Helen or Cleopatra, or the Milo Venus, is in that list of things that we take for granted. But I will copy down a too-little-known passage that speaks of the Welsh mountains from a beautifully, touchingly human and personal point of view. It was written by that great Nature-lover, and my dear friend, Edward Thomas, one of the many precious lives lost in the war and not easily to be spared:

"In their shape, there is something human, or suggesting human work, in these hills. Castles, or less noble masonry, noble when fallen, look thus in their ruins, and become thus tricked with delicate verdure and flowers. A great plough, driven at random through frosty country, would have turned up half-mile clods like these. And at twilight there is a ridge like an extended giant with raised knees and chin thrown back; and often have I seen a horned summit, like a Pan, capture the white moon.

"This mountain ahead is not only old, but with its uncovered rock and broken boulders and twisted trees, that look as if a child had gathered garlands and put them in play upon the ancient stems, it declares mightily, if vaguely, the immense past that it has seen. There are English hills that remind us that this land also was once in Arcady; but they speak of nothing since; they bear no wrinkles, no wounds, no trophies. But by this mountain you cannot be really at ease until in some way you have travelled through all history. For it has not been as nothing to it that Persia, Carthage, Greece and Rome, and Spain have been great, and are not. It has been worn by the footprints

of time which have elsewhere but made the grass a little deeper, or renewed the woods. It has sat motionless, looking on the world; it has grown wrinkled; it is all memory. Were it and its fellows to depart, we should not know how old we were; for we should only have books. Therefore I love it. It offers no illusions. Its roads are winding and rough. The grass is thin; the shelter scarce; the valley crops moderate; the water pure. It offers no illusions; for it is clear, as it is not in an exuberant English county, that the

CRIB GOCH, NEAR LLANBERIS.

world is old and troubled, and that light and warmth and fellowship are good. Sometimes comes a thought that it is a huge gravestone, so is it worn, so obscure, so brief its legend. It belongs to the past, to the dead; and the dead, as they are more numerous, so here they are greater than we, and we only great because we shall one day be of their number."

Coming now to the question of the geology of the Welsh rocks, I imagine myself speaking to a reader who has followed my story thus far with intelligent

interest, and asking him what he would expect these Welsh rocks to be. Note his answer:

"You began with the fairly recent rocks around London; and you have led us gradually to older and still older rocks, travelling westward and northward; so that it appears that the British rocks are tilted from north-west to south-west, generally speaking. Therefore I should expect to find in Wales some Devonian rocks in the south, but older and older rocks as we travel north and west."

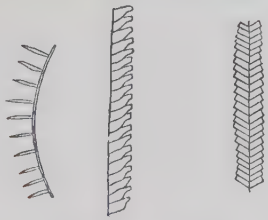
Certainly; a very good answer, and a true one. Note, Devonian and Carboniferous rocks in South Wales; but farther north and west, rocks older than Devonian time, Nos. 13, 12, and 11, named Silurian, Ordovician, and Cambrian, after three famous old Welsh tribes. What would you expect these rocks to be like? The answer comes:

"Up to now we have found, time after time, each period made up of a compound of sandstones and limestones, with clays or muds; the fossils have been older and older—that is to say, more and more primitive in type, as we have worked backwards. Therefore we now expect the same thing, sedimentary sandstones, coarse or fine, with limestones and muds; the latter we expect, from last chapter, will be in the form of Slates; we also expect many traces of volcanic action."

Right again. This is just what we do find in the Welsh rocks, in the time-hardened, fire-tested, weather-worn, deep-wrinkled rocks that give the tragic grandeur to Welsh scenery, and that have so stirred the imaginations of long generations of the fine Welsh folk.

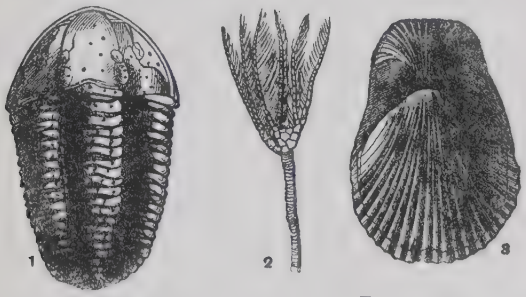
The fossils, of which there are plenty, are of shells and of corals. But in addition there were primitive ancient things called Trilobites and Graptolites. Nothing much like a Graptolite is living to-day; but in America there is an armoured creature called a King-crab, which is a sort of descendant of the Trilobites. (Trilobites were also common in Devonian times.) In their flexible, jointed armour these crea-

tures have a quaint, almost comical appearance. There is a suggestion of the mountebank or court jester in their queer make-up. You begin to be fond of them at once. They can be seen in any good geological museum. They appear to have been the highest existent form of life in Cambrian days.



GRAPTOLITES.

Silurian and Ordovician rocks are also found in the English Lake District and in the hills on the Scottish side of the Border. Cambrian rocks are well developed down the east coast of North America. These



1, TRILOBITE ; 2, CRINOID ; 3, BRACHIOPOD.

very ancient rocks are oft-found, interesting, important. In the Upper Silurian rocks remains of fish (spines, teeth, scales, and so forth) are discovered for the first time in the world's geological records.

What about the rocks before the Cambrian? Do we still go back and back, to other and almost endless

sequences of sandstones, clays, and limestones, with fossil creatures still more and more primitive?

Here I must pause, for this will take some explanation; but first let me call your attention to the words at the head of the chapter—"The Curtain and the Mystery."

Geologists, by steady, patient labour, by much brilliant thought and observation, by the invaluable services of an army of devoted amateurs added to the fine, clear thinking of the leaders, have built up a science full of fact and interest, a supremely dramatic story of life on this Earth; but they do not know all the story; there are mysteries that still baffle them. One of the deepest of these mysteries concerns life in the times before the Cambrian. It is a sense of this mystery that makes Mr. Wells cry out, in the third chapter of his very able "Outline of History":

"The Record of the Rocks does not begin with any group of closely related forms from which all subsequent and existing creatures are descended. It begins in the midst of the game, with nearly every main division of the animal kingdom already represented. Plants are already plants, and animals animals. The curtain rises on a drama in the sea that has already begun, and that has been going on for some time."

The same difficulty is admitted and tackled, as far as at present it can be, in Professor J. W. Gregory's terse little volume, "The Making of the Earth," wherein he quotes Dr. Evans and his clever statement of the case. And back in the time of Darwin, though Geology was then much behind what it is to-day, this difficulty had already loomed large, as is apparent in the tenth and fifteenth chapters of "The Origin of Species."

Let us consider the facts with care. In the Highlands of Scotland, on the north-west coast of Ireland, and in Norway and other places where immeasurably old rocks are found, we get the series numbered from 4 to 9 on our map, and called "Archæan," which means exceedingly old, or "Metamorphic," which

means "changed." In point of fact their age is so stupendously great, and they have been subjected to such changes, such heat, pressure, contortion, that their entire structure, both mineral and physical, has been entirely altered.

We can only guess, vaguely, what once they were, and we may be wrong all the time. Some hold that they were once sedimentary rocks, and may have contained fossils of a most primitive type. We do not know. It is as well, sometimes, to admit our ignorance. We admit it here, when we come to the Metamorphic rocks, to those hoary giants whose massive beauty and almost violent shapes make the Highlands of Scotland so grand in their supreme appeal to the imagination.

Between these ancient mysteries in rock-form and the Cambrians there are some very, very old sandstones, the Torridon and Longmynd Sandstones, numbered 10. Immensely old though these are, they appear infinitely newer than the Metamorphic rocks, which seem to stand behind an almost appalling gap in time. The Torridon and Longmynd Sandstones are rocks in the manner which we know to-day. The Archæan Metamorphic rocks are not. Hence the difference.

Fossils appear to be very scarce in the Torridon Sandstone, though there are a few vague traces. The Cambrian life, so well represented, finds no clue to its richness in the older Sandstones. The mystery maintains itself. Some day we may be able to extend our fossil list backwards to these ancient Sandstones. At present we cannot.

Taking the fossil list as we know it at present, we own to more than one gap, more than one mystery; but two stand out, more difficult of solution than any other: the life before Cambrian time and the first beginnings of Man. With the merest shadow of earlier suggestion, life appears, full and rich, in Cambrian times. And also with the merest shadow of earlier suggestion, Man appears in early Stone

Age time. And just as Cambrian life appears, to dominate hereafter the scene, so also does Man. In each case the entrance is dramatic. Suddenly a chief actor comes, commanding the stage and leading the drama henceforth. It is one of the many thrills of a science that is never tame.

Leaving aside these mysteries, the fossil record is a noble and inspiring one. The story of the progress of life to higher and ever higher forms is one of the noblest that we know. I need not comment here on the many and obvious ethical, moral, and religious aspects of this record; sorry indeed would one feel for the man who could not see in it a permanent inspiration. Man has been given the mind, the judgment, the spirit, the soul, and higher emotions that enable him to be inspired by such a record; it is something for which each and all of us may be supremely grateful. And we, who have been given eyes to see this stupendous drama of Time and Effort, have even played in it, each our little part. And we have, most of us, with God's help, played this part like Men.

CHAPTER VIII

VOLCANIC STRESS

In previous chapters I have more than once spoken of land being raised by pressure from beneath. To the minds of some people, this always, at once, gives the idea of a very violent volcanic disturbance, of a terrible earthquake, of something very stressful and severe.

You might just as well think that every great enterprise undertaken by men was carried out by persons in a raging temper, as imagine that important Earth-movements were always violent. But just as the big plans of great men have been brought to success by steady persistence rather than by moments of fury, so the great movements that have shaped the surface of

the Earth have been of the slow, persistent, irresistible kind.

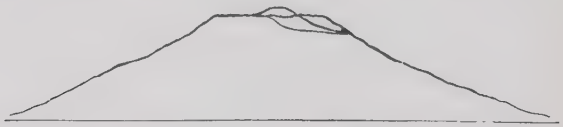
Think of it. The great mountain system of Southern Eurasia is one chain, under different names, and includes the Pyrenees, the Alps, the Himalayas, and the mountains between, in the same line of route. It must be at least 7,000 miles long, and its top peak is nearly six miles high. Imagine such a range going up as the result of one violent outbreak! The explosion would have blown the earth to pieces, and some of the bits might have shattered the moon! Oh no! The theory of violence will not do at any price. In Nature, as in Man, the road of violence is not the road to great achievement.

"A great and strong wind rent the mountains, and brake in pieces the rocks; but the Lord was not in the wind: and after the wind, an earthquake; but the Lord was not in the earthquake: and after the earthquake, a fire; but the Lord was not in the fire: and after the fire, a still small voice . . ." (1 Kings xix.).

It is the still small voice of power and purpose that really does the work, let the earthquakes bluster how they will. But the world is very human, and, like to us, it has its moments of temper when it makes the sparks fly; and though these fits of passion have less ultimate effect than the slow, steady, persistent moods, yet it is as well to see what does happen when Mr. (or Mrs.) Earth has a thorough fit of tantrums; so let us take a few typical episodes of which we happen to have sufficiently complete records; there is no need to multiply cases. Those that we do consider will, probably, not tempt any reader to take the first train or boat to the nearest earthquake zone.

The first with which we will deal is memorable because it has provided us with what may fairly be described as "a fossil town." When volcanic ash falls on plants, and, while killing them, preserves them, entombed, for the instruction of the later generation that discovers them, we speak of them as "fossil plants." Surely, by the same use of language, Pompeii is a *fossil town?*

This lovely Roman city, of 20,000 inhabitants, was built near the shore of the beautiful Bay of Naples, and attracted many of the rich and cultured Romans during the reigns of the early Emperors. True, it was at the southern foot of Vesuvius; but this volcano had been inactive for several hundred years, and no one appeared to fear it. In A.D. 63, however, Pompeii was badly shaken and damaged by an earthquake; but just as, in modern days, San Francisco and other fine towns, in beautiful or valuable situations, have been rebuilt after earthquakes have uttered a sufficiently memorable threat, so in the days of Nero the Romans set quickly about to repair the damage done to their delightful Pompeii, and after sixteen years, in the beginning of the reign of Titus, much of it was already rebuilt, and busy masons, with well-



Outline of Vesuvius.

tooled blocks of stone, were completing the Forum in a grander style than before. They might have saved their labour.

On August 24, A.D. 79, Vesuvius burst into eruption, and within a few hours Pompeii and two other towns were buried. They were not destroyed by lava-streams; had this been so, there would not be visible the wonderful "fossil town" that attracts visitors from all parts of the Earth to-day. Pompeii was literally smothered up by a rain of volcanic ashes, dust, and small fragments, aided by streams of liquid mud. The eruption was accompanied by earthquake shocks and a violent thunderstorm, deluges of rain causing mud-streams, while the sea rolled back from the shores of the bay; had it rolled forward on to the land, the destruction would have been even greater.

The elder Pliny, the writer of a celebrated Roman Natural History, one of the most enlightened and most humane of the Romans of that day, was in command of a Roman fleet that was stationed in the Bay of Naples. His home was near Pompeii; and on that terrible afternoon he worked hard, trying to take refugees on to his ships. But the disaster had been too violent and too sudden; his efforts were in vain. With a courage that amounted to rashness, he went to his home, which had survived the wreckage; there, on the following morning, he died, suffocated by the fumes. His adopted son, the younger Pliny, afterwards wrote to the historian Tacitus a full account of the catastrophe. This letter still exists, and is our guide to the whole course of these tragic happenings.

He speaks of flames of fire shooting out of the crater, of the black cloud that filled the upper air. The ground quivered, the ashes fell in hot showers, as he hurried out with his mother into a jostling and fear-stricken crowd. The old lady very heroically begged him to leave her, as he could get away quickly, while her movements were slow. He refused to desert her.

"I looked around," he says; "thick, smoky darkness rolled menacingly over us from behind; it followed us, spreading like a flood over the earth. I advised that we should escape to a side-track while we could yet see, as I feared that we might fall and be trampled to death by the crowd. We had scarcely got away from the throng when we were covered by a darkness thicker than night."

He describes how the men and women tied cushions over their heads, lest their skulls should be cracked by falling stones; and also how they had to keep shaking the ashes from these cushions, as the weight grew intolerable. Both he and many others thought that the day had come when the world would pass away.

Pompeii was buried under a layer of ashes 20 feet thick. Fifteen hundred years passed away. Fields, trees, even houses, were developed on this ash-bed; for volcanic ash makes quite good soil. Then sud-

denly came the idea, Why not dig out the old city? And so we began to find our fossil town.

This is hardly the place to describe Pompeii, but let us consider one or two of the things found in it—for instance, the dead woman whose hands are clasping a bag of gold and silver. . . . In Chapter V. I have already discussed the permanence, under certain conditions, of things that one would think to be slight and temporary; and here, in Pompeii, we still see the cheeky sentences that mischievous young Romans scribbled on the walls eighteen and a half centuries ago. One of them in particular is a cruel, cowardly jibe: "Enjoy the fire, Christian?"

Fifteen years before the destruction of Pompeii, Nero, who had been himself accused of causing the great fire of Rome, laid the blame on to the Christians, whom he punished with merciless cruelty.

"The Emperor," writes Tacitus, "visited these men with the most exquisite tortures, and their torments were embittered by insult and derision. Some were nailed on crosses, others were sewn up in the skins of wild animals and given over to furious dogs; others, smeared over with tar, were lit and used as torches to brighten the night. The gardens of Nero were chosen for this display, together with a horse-race, all being honoured by the presence of the Emperor. . . . But many of the public pitied these poor wretches, blaming the cruelty of the tyrant."

Tacitus thus mentions two sections of the public—those who showered insult and derision, those who showed pity. Among the former was the thoughtless jeerer who scribbled that awful jibe on Pompeii walls. And one cannot help wondering whether, fifteen years afterwards, this heartless youth, now grown to manhood, was among those who, in their threatened town, found themselves struggling vainly for escape from the deluge of hot ashes and the asphyxia of suffocating fumes; whether in that moment he remembered the only pity that he had shown for brave men in the throes of violent death; whether he showed a heroism

measurable with theirs; or whether, when his own time came, the flippant jeerer turned to a screaming coward.

In Iceland, in the year 1721, owing to a weird co-operation between fire and frost, volcanic action led to what might have been a frightful disaster had it happened in a more populated country; this event remains as dramatic evidence of the awful power of natural forces when escaping from the physical controls that usually operate. On this occasion the fiery forces did not even burst out at the surface, but merely caused heat, melting the underpart of some of the glaciers, and turning the usual extremely slow movement of these giant ploughs into a devastating rush.

"A stream burst forth," says the official account, "consisting of half-melted snow and masses of ice, which tumbled about in the sea like floating islands; while another stream, flowing south-east, did immense damage to the land. The first of these filled the sea with so much ice that even from the mountains it was impossible to see open water. When broken up by the waves, some of it drifted west and entered the rivers. The greater portion of it, however, remained fixed, about seven miles from land, in six hundred feet of water. A similar stream broke loose on the following day, submerging the masses of ice already in the sea. It carried with it many rocks that stood in its way, including one a hundred and twenty feet high, which entirely disappeared."

No wonder we are told that on the whole of the route taken by these ice-streams the land, when laid bare, was planed absolutely smooth, as by a gigantic, irresistible plane.

We Britons are lucky to be living in a land where neither glacier, volcano, nor earthquake is known, though all these three disturbances to a quiet life were in existence in our islands in the geological past. In a land of regular earthquakes, such as Japan, special forms of building have to be adopted. I have seen photographs of Japanese temples with a highly ingenious ball-and-socket arrangement where the

columns meet the roof. This makes it possible for the temple to be shaken without falling. The dwelling-houses are usually made very light, so that it will not much matter if the home collapses on the heads of the family. A light wooden house, with the inner walls, between room and room, made of paper, and with a strong oak table on the floor of the main downstairs room, makes an excellent earthquake residence. While the Earth is rocking, the family seats itself under the strong oak table; if the house falls, no one is one penny the worse! Yet all the cleverness of this wise and experienced people will go for nothing in such appalling disasters as the great Tokio earthquake of 1923.

In some of the earthquake countries of South America, where mild shocks occur regularly several times a week, the people become alarmed if there is no shock. You will find them with long faces, saying to one another in frightened voices: "What will happen? There has not been an earthquake for over a fortnight!"

They have every reason for their alarm. They know quite well that the mild, regular shocks act as a safety valve, and that as long as these last the Earth is "letting off steam." If anything hinders these mild, protective shocks, then the Earth-forces are bottled up, and when they have gathered enough power the delayed shock will be all the more terrible.

The most dramatic eruption of modern times was that which, in 1883, during my own lifetime, devastated the island of Krakatoa. This small volcanic island lies just between Sumatra and Java, only a few degrees south of the Equator; it is well in the earthquake zone; its big neighbour, Java, contains forty-nine great volcanic mountains. In Krakatoa are the remains of an old volcano that in the past has nearly blown itself to pieces by its own violence. Luckily, the dangers of this island were well known; and though its splendid forests attracted visitors, it was uninhabited.

Several times during the first half of 1883 violent eruptions took place on the island. Landing-parties found volcanic ash all over the ground, and forests destroyed. The climax came on August 26 and 27. Ships in the neighbourhood, which escaped destruction as if by a miracle, were able to give a full account of the happenings. White-hot lava rolled down the mountain, showers of ashes fell on all sides; darkness, lightning, thunder, sea-disturbance, with huge, excited waves—all these were duly noted. The nearest ship, some distance away, had three feet of ashes on her deck before she could escape.

A series of violent explosions was heard, and their effects were seen. The white-hot lava, cooling on top, kept forming a scum; and this scum was constantly blown away by the steam and boiling gases of the volcano. So much of the island was blown away by the explosions that the sea began to rush in, meeting the incredibly hot material of the eruption.

The sea-water, hardening and cooling the top layer, shut in the violent gases, closed the safety valve. Four tremendous explosions took place, with a sound so furiously violent that it was heard 2,000 miles away, in Ceylon and Australia; some say 3,000 miles away. The greater part of the island was blown to pieces; and so much of its rock was torn asunder that in one place, where land had been, the sea became a thousand feet deep.

Immense waves were formed, which did terrible damage to shipping. Towns along the sea-coasts were washed away. Nearly 40,000 people perished. The waves dashed round the world, striking the coasts of Africa and America; they were even recorded, in a weakened form, on the coasts of Cornwall and Dorset. The air-waves, affecting the barometers all over the world, were proved to have travelled round the Globe two or three times.

Such was the havoc caused by one eruption, in one small volcanic island. But the world has not been shaped by such violent means. Steady, persistent

forces, always working, never resting, have shaped this beautiful, interesting Globe of ours. The eruption of Krakatoa is like a drunken orgy of the Earth-forces; the sober, steady building up of the world's huge mass of sedimentary rocks is infinitely more impressive.

CHAPTER IX

THE FIRE-FORMED ROCKS

We must now study an important and interesting group, the Fire-formed rocks. Geologists divide these into two classes—the Volcanic and the Plutonic. The Volcanic are those which were actually pushed up to the Earth's surface by volcanic action, being, therefore, either hardened lavas or masses of coarse or fine volcanic ash. The Plutonic have been pushed upwards, from what is often called "the bowels of the Earth" (though actually not so very far below the crust), but have not had any outlet to the surface. They have burst their way into the under-parts of the crust without breaking right through. They have cooled and hardened; and thousands or millions of years later, when the rocks over them have all or partly worn away, these great granite masses have shown themselves, and have in turn fought their stern fight with the restless forces of rock-destruction. A mass of rocks thus laid bare on the earth's surface is called an "outcrop." Of course, all outcrops are not Plutonic or Volcanic. Sedimentary rocks form outcrops too.

Volcanoes may be divided into three classes: First the volcanic mountain, like Vesuvius or Cotopaxi, which, to use a commercial simile, may be called a wholesale dealer in lava; this is the source of the lava-streams, and occasionally a centre of violent destruction. Then the small ash volcanoes, that usually occur in groups; these are smaller in action, and are the re-

tailers of lava. But, thirdly, lava sometimes bursts up through a series of cracks in the Earth's crust, making lava-fields, such as we find in Iceland. This may be compared with trade done, not at one large shop, but by a series of coster-barrows. And traces of all these types, of volcanic mountains, of ash-cones, and of fissure-lavas, are found in our record of past ages, in Britain and elsewhere.

Hardened lava usually takes the form of Basalt, a very interesting rock wherever found. I once heard a very young teacher give a lesson on Basalt, in a way that aroused my suspicions. When the lesson was over, and the class had gone, I quietly asked:

"Would you know Basalt if I showed you a piece?"

LAVA-DYKES.

"No, I'm afraid not."

"What colour do you suppose it is?"

"I don't know, but I would guess white."

"It happens to be nearly black. I'll bring you a piece next week."

That is what comes when we give lessons on subjects that we have not properly mastered. Next week both he and all his class had a thorough examination of a piece of the real stuff, the guaranteed product of a real prehistoric British volcano!

The Plutonic rocks, it may be noted, are called "intrusive" on the Geological Map of the British Islands to which I have so often referred. In Geology, as in every other branch of human activity, there are often

two or three names for the same thing. Of these rocks, Granite is by far the most important. In one of the guesses of the clever early geologists it was thought that Granite was probably the material of the earliest crust of the Earth, and that from it all later rocks were derived. But the researches of chemists proved that some of the materials of which Granite is composed can only be formed under intense pressure, a pressure that must have been given by other rocks lying over it during its formation.

Granite is a compound of many substances, but chiefly of acid felspar, quartz, and mica. The felspar varies in colour from a deadish white, through pink, to red. The mica is very obvious, in small glittering flakes that can be jerked off by a twist of the point of a knife or chisel. These are neither of them elements, but can be split up in a chemical laboratory; both of them contain silica and alumina (which we know from Chapter I. to exist in clay), and one or more oxides. It is not the material but the proportion that gives these minerals their character.

Mica is specially important, as it is a great source of beauty in rocks (see also Chapter XI.). Some forms of it are used for ornamental purposes. Although mica is usually seen in small sparkling grains, it exists, in India and elsewhere, in very large crystals. A variety called "talc," thin and transparent, is used instead of glass in places where there is sideway strain, as talc bends without breaking.

Quartz is a very simple compound. It consists of 1 part of silicon to 2 parts of oxygen, and is therefore called by chemists SiO_2. But note this: If a chemist melts down quartz, and then recrystallises the exact material of which it was formed, he does not get quartz, but a different form of silica. Quartz can only be formed under conditions of very great pressure. This important discovery proves that Granite could never have been formed as a surface rock. The rock most nearly approaching the original crust of the Earth must be Basalt.

There are many forms of Granite, all of them very handsome. The ancient Egyptians, thousands of years ago, used granites, with other stones, in their temples. A well-sawn, well-polished Granite is one of the richest of our building-stones. Shap Granite, from near the English Lake District, has well-formed crystals of reddish-pink felspar, and is often seen in London buildings; for instance, in the pillars in front of that very noble station, St. Pancras. Dartmoor Granite has bold milky-white crystals of felspar which make it a favourite with monumental masons. It can be seen at London Bridge. The steps below the Albert Memorial are of an Ulster Granite, from the Mourne Mountains. In each case the architect chose the Granite that suited best the scheme that he had in mind; for both the Albert Memorial and St. Pancras Station were planned by the same architect, Sir Gilbert Scott: the first as pleased Queen Victoria, and the second as pleased himself.

But these decorative invasions of Granite into the richer buildings of a brick city of the Clay do not really show us what Granite can do as a building-stone. To know that we must go to Aberdeen, where this noble rock, quarried on the spot, is used for building the whole city. Stand on the sea-front of Aberdeen when sunshine has just followed a summer shower, with the waves chanting their eternal hymn behind you, and the mountains raising their hoary heads into the sky before you; and there, on its ledge betwixt mountains and sea, glittering and sparkling with a million crystal gems, the Granite City of the North will unfold to you the noblest beauties of this superb stone, stress-born, from the throes and paroxysms of Earth's molten entrails.

Laurwigite, a dark Norwegian Plutonic rock, is found below the windows of the S.P.C.K. building.

Basalt, hardened lava, is a close-grained rock of a dull, dark, greeny-black colour, that makes sternly romantic cliffs. It is much harder than the sedimentary rocks, though decidedly softer than Granite.

It is used for road surfaces where it is quarried, and breaks very irregularly. An intelligent boy or girl, when first handling a piece, will immediately cry out: "It is much heavier than ordinary rock!"

Rough Test.—I put a piece of Basalt in a jam-jar, and poured in water till level with the top. Then I carefully took out the Basalt and put in pieces of Granite till the water-level was at the top as before. Then I repeated this with Millstone Grit. By this means I got equal bulk of the three rocks. On weighing, the Basalt was just a trifle heavier than the Granite; but it outweighed the Millstone Grit in the proportion of 5 to 4.

I was once taking a group of children for a walk in Derbyshire, when we came upon a heap of Basalt, chipped ready for road-repairing. I was explaining the nature of this fine rock to the children when the roadman came up, anxious to know what was happening. I said to him: "I was just explaining that this rock was pushed up out of the Earth by a prehistoric volcanic eruption." He answered: "There'll be another volcanic eruption if them boys of yourn don't get off that 'eap!"

We obeyed without arguing; clearly, no sensible man would stop to argue with a volcano, professional or amateur. Vesuvius in eruption would get the better of the cleverest professor.

Basaltic outcrops are often the cause of waterfalls; this rock is tougher than the sedimentary rock through which it has forced itself, and therefore stands the wear and tear of the elements more successfully. The softer rocks wear away, and the dark ledge of ancient lava rears itself boldly. Where the whole valley is of one class of rock, the mountain river may make a series of rapids or of small falls, but not one big, dramatic fall. The big fall comes where the black cliff is left, evidence of ancient volcanic stress. Hence several Welsh falls are called "Rhyader Ddu," or "Black Waterfall."

I was once staying with friends in the "Devonian"

part of the Scottish Highlands; they offered to take me to see a big waterfall. I remarked casually:

"The rock behind that waterfall will be black."

"Then you have seen the fall?"

"No, I have not; but the rock behind it will be black."

"You have read about it? Or someone has told you about it?"

"No, neither one nor the other; but the rock behind that fall will be black."

"How can you possibly know? The rock on each side of the valley is red."

"Yes; but the rock behind that waterfall will be black."

Of course it was; and I explained to them why I knew.

The "High Force," a splendid waterfall in Teesdale, is a fine example. The dark volcanic rocks gain an added beauty and charm from the sparkle of the water and the lush green of the rich fernery and moss. Note specially any waterfall that you see, and try to ascertain its origin. Map out its line of descent.

Fine examples of volcanic rock are seen in the bold cliffs on which stand Edinburgh Castle and Dumbarton Castle; also at Largo Law, in Fife, and at Keswick Castle Hill. There are many examples. Snowdon is one of our most interesting volcanic mountains. Its summit is of volcanic ash, and contains very old fossils. Lower down are lavas; quite low down we come to beds of ancient grits; and below all, slates. The slate quarries of Llanberis are perhaps the most famous in the world. It is supposed that the volcanic ash that now forms the summit of Snowdon fell on the sea, and that the lavas are submarine. After that followed a steady and very great upheaval; the last processes have been of gradual tearing down of the great mountain thus formed. The present Snowdon, still one of the most romantically beautiful mountains in the world, is just the stump of the huge Snowdon that once was.

The clamber up, by either route, carries one over a longer mileage of broken rock fragments than I have encountered anywhere.

If we want examples from Britain of great fields of lava, which once spread from a series of fissures, we would first turn to the volcanic field of Antrim, with that highly interesting formation "the Giant's Causeway," due to the regular shrinkage of the basaltic rock. But another highly remarkable and perhaps less often described field is that of the Lower Tay Valley.

SNOWDON, FROM LLANBERIS LAKE.

Let us stand on the south side of the mouth of the river, looking north, across that noble firth; behind us stretches the sandy waste of Tentsmuir, only just above sea-level. All that sand has been brought down by the Tay in quite recent times. Across the water, the sandy spit of Buddon is also recent and river-formed. And if the tide is low, we see great sandbanks right across the river—river-sand, Tay-carried; seals are basking there in the sunshine. And note that patient, hard-working little dredger; if she were not

always at work the Tay would erect such a sandy barrier that our ships could not enter Dundee; and the river, blocked by itself, might overflow the lower streets of Tayport.

Behind us, and also on the other side of the river, are breezy, hummocky hills. Every one is of hardened lava, of true volcanic rock. If we follow up the river, walking westwards, we see a capital illustration in the cutting just past the station; there the dark greeny-black basalt is obvious, and of a stern beauty. We follow the water along the braes; all those bumpy rocks, that so finely enshrine the wild-flower, are old lavas. And so all the charming way to Newport.

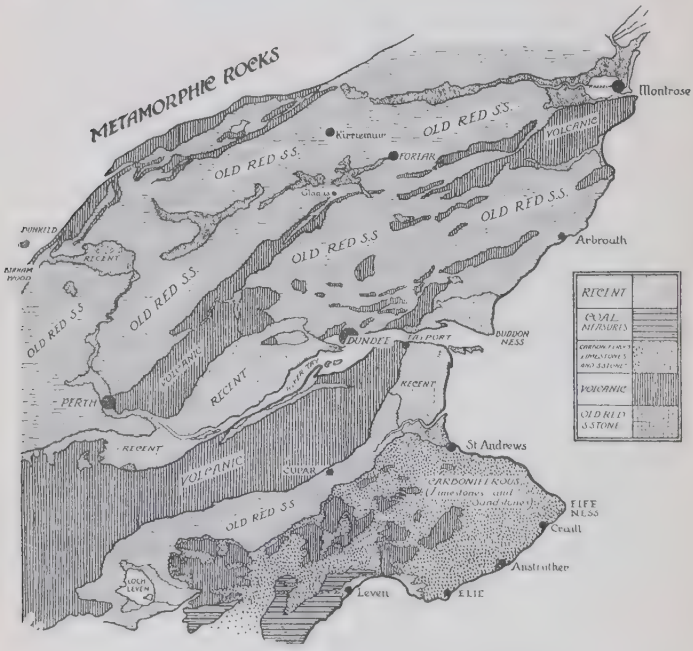
That smoke that we saw in the distant haze might make the volcanic suggestion a little more vivid, but it is only the typical atmosphere of Bonnie Dundee. That is a smoke of man's making, and it probably kills more than the volcanoes have ever killed.

At Newport we ferry over to Dundee itself, then take the boat to Perth. The river-banks are fertile; volcanic rock, as it breaks up, makes splendid growing soil full of the needed minerals. The shapely hills on either side are volcanic still, though the river-bank for a little way in on either side is now Scottish-Devonian, and by the waterside there are several alluvial banks of recent formation. This charming country was often painted by Millais; it is noble and pensive; the Tay is a lordly stream. When the river takes a sharp turn, the volcanic rock stretches down to both shores again.

That hill seen in the distance as we near Perth recalls another group of suggestions. It is Dunsinane; we are in the Macbeth country. And our imaginations, aroused by the greatness of the river, begin to evolve the geology of Macbeth. The scene of the Witches is acted on "a heath near Forres." Forres is in a narrow belt of the Scottish-Devonian, but that heath *near* Forres must surely have been among those ancient, crystalline rocks of Scotland, whose origin is lost in the vastest mysteries of time. Here it was that the "secret, black, and midnight hags" must meet, in

a rock-country as secret, as cryptographic as themselves. Inspired by the profound riddle of these antique cliffs, they plot and plan their "deed without a name."

Then the castle of Glamis, the castle of the murder, is in the district of the Scottish Old Red Sandstone. Here it was that on "the unruly night" of the



SURFACE ROCKS, FIRTH OF TAY DISTRICT.

assassination rain poured on those red rocks till every one of them seemed to stream with blood, and Nature shuddered at the foul abuse of hospitality that made treason uglier and murder bloodier.

And now, lastly, this castle of Dunsinane, this volcanic ground. Read the last act of the tragedy; if this be not volcanic stuff, one would seek it in vain

among the world's tragic poets. Yes, that last act is volcanic; and here ends the geology of Macbeth.

And now I hear the murmur of the objector, saying that Shakespeare knew no Geology, and had never visited Scotland. True, objector; but these two facts, that seem to you so final, shake me not in the least in my contention. For it is precisely the immortal gift of the world's greatest creative artists, of Shakespeare, of Beethoven, of Michelangelo, that their work does not stop at what they actually said or knew themselves. They so uplift our imaginations that the flight does not, cannot, stop even where they left it. Swept into a mood of imaginative response by the mighty tragedy of Macbeth, we read the story written in rocks that were old millions of years before Shakespeare was born. And in the imaginative sense we are right; for poetry is not bounded by those considerations that are excellent in the multiplication table.

And Geology is the most poetical of all the sciences. A million stories of Man's making are founded on the fascination that the rocks have always held for him; and the true story that the rocks themselves tell blends harmoniously with them all.

CHAPTER X

THE ROCKS AS A WHOLE

In our first nine chapters we have dealt, all too briefly, with the Water-carried rocks (Sedimentary); with the Fire-formed rocks (Plutonic and Volcanic); with those mysterious rocks so scarred by time that their story evades while it fascinates us (the Metamorphic rocks); and to this we should add those Sedimentary rocks that are wind-carried, in desert conditions or, in the form of sand-dunes, by the coast—the finest sand-dunes that I have ever seen being those on the north shore of Holy Island, Northumberland, that island which unites charms of Scenery, Botany, Geology, History, Story,

Legend, and glorious air, in its four square miles of territory.

All too briefly the story of these classes of rock has been hinted at rather than told. There are plenty of more advanced books for those who wish to pursue the matter further. This present chapter I wish to devote to shaping up the story told in the previous chapters. There are several points that cry out for further attention.

The first of these deals with the Fire-formed rocks. Look again at your Geological Map; you will find the Fire-formed rocks numbered from 1 to 3, *but you must not think from this that they occur in this order,* taking their places before No. 4. Such an idea would be absurd. They are so numbered because in theory they represent the original crust of the Earth more closely than any of the rest of the series; but a moment's thought will make it clear to you that No. 3, the Basalt or hardened lava, is being "formed"—that is to say, thrown on to the face of the Earth—to-day whenever there is a volcanic eruption.

In fact, the whole question of the age of Fire-formed rocks is on a different basis to the question of the age of Sedimentary rocks. The latter pursue a definite order all over the world—an order that can be verified by their position and by their fossils. But a Basalt, obviously, could be found between any two of the Sedimentary series, according to when the eruption took place. And volcanic rock is seldom fossil-bearing, though when it has fallen as fine ash it does sometimes enclose plant-remains or other fossil material.

That is why No. 3 is labelled in four different ways, as "Tertiary," "Permian," "Devonian," "Pre-Devonian." Basalt is Basalt, all the world over; but it is a matter of great interest and importance to the geologist *when* the particular eruption took place that brought to the surface any stated flow or field of basaltic rock; and this can be found out by a variety of ways, some of which may at once occur to you as you read this.

For instance, in our last chapter we made a short study of the volcanic rocks of the valley of the Tay, and mentioned the strip of Devonian which stood in intimate connexion with them. It is quite obvious, from the closeness of the relation, that this volcanic rock was from an outburst in Devonian time, and you will find it so marked on your map. If the associated sedimentary beds were entirely covered and hidden, it would be far more difficult; but in practical work we seldom, if ever, find a lava-cone or lava-field without some reliable feature that gives away its age. Vulcan, being a mere male, can be pinned down definitely to his date.

A very fine example of this occurs in Scotland, in the Island of Eigg (between the Island of Rum and the mainland of Inverness-shire). This small isle consists of a small corner of Jurassic rock, with a very bold outcrop of Basalt.

It would be easy to jump to the conclusion that the lava burst out in Jurassic times; but that would be most unlikely, because all over Britain there is no trace of volcanic action either during or near the Jurassic period—in fact, the whole of the Secondary or Mesozoic period passed quietly in Britain, with no volcanic stress at all. So that no one would be disposed to regard the corner of one little island as disproof of so strong a proposition as the quietude, here in Britain, during Secondary time.

Again, the whole of the black lavas from Antrim to Skye are of a similar type, and there is little room to doubt that at one time this lava-sheet was continuous; the sinking of the land and the wearing action of the sea have together destroyed three-fourths of this great volcanic field; and it can be proved in many places to have been an outburst in Eocene times, for in Antrim it rests upon the Chalk.

Luckily, that fine geologist Sir A. Geikie, whose writings upon the rocks of Scotland are so noteworthy, discovered at Eigg, under the upper volcanic rock, and above a lower outcrop, a belt of Gravel, the remains of

an old river-bed. This contains fossil branches of Eocene age, which of course settles the matter.

With regard to the Chalk in Antrim, this opens out another interesting line of thought. There is practically no true Chalk in Ireland, though there are a few Sands and a thin belt of Limestone, all containing fossils of Chalk age. Such Chalk as there was in Ireland was probably very thin, and has since been almost entirely worn away. But where Basalt has put a strong capping over it, it has been protected.

Let me here stop to point out the alert logic of Geology. We are made to observe and to think all the time. The wonderful work of Euclid in the sphere of sheer reasoning is matched by Geology. Geology ranges from the soundest reasoning of the mathematician to the most splendid dreams of the poetry of Creation; that is why I am so keen about it.

Volcanic rock of Permian and Carboniferous age is best seen in Britain in the vast masses along the main valley of Scotland, that which lies between the Highlands and the Border hills. There are bold hills to the west of Glasgow of this lava; Dumbarton Castle stands on one of them. You can trace it on a strong chain of hills lying on the south side of a line drawn from Dumbarton to Stirling. In England there are isolated instances in the Derbyshire Pennines, the local quarrymen calling this rock "Toadstone."

Volcanic rocks of Pre-Devonian age are well seen in Wales, especially grand being the noble head of Cader Idris; but they are even more splendid in the English Lake District, where they form the very centre and focus of the whole of the scenery. Those lovely lakes, Haweswater, Wastwater, Thirlmere; the top half of Ullswater and the extreme top end of Windermere; the noble mountains, Scawfell, Helvellyn, Coniston Old Man, Langdale Pikes—all these are in the province of the Lake District Volcanic series. It is reckoned to be of Ordovician age.

There is a big "fault" at the lower end of Wastwater, where the Lavas meet the Granites. A further

slip on the part of this fault was supposed to be the cause of the mild Cumbrian earthquake of 1901.

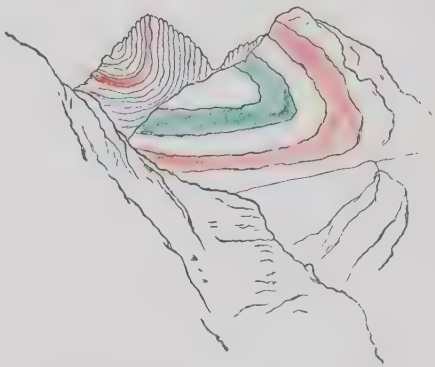
To go abroad for our next instance, Mount Etna presents an interesting case. Although, by her name, a Lady-volcano, she does not succeed in concealing her age; but then we must remember that she is, geologically speaking, very young. Though her lavas rise 11,000 feet, on her flanks, 1,200 feet up, are beds of shells, modern in type, of Pliocene age. A mere youngster, and still frisky. In 1923 her conduct, like that of the modern young woman in general, is "giving anxiety"!

This brings us to the whole question of the age of mountains. In considering this, two things have to be thought of: one is the actual age of the rocks themselves; the other is the period during which those rocks were raised up. Obviously, the whole theory of water-borne sedimentary rocks tells us that as they are laid down on the lower levels, they must be elevated at a later period. Thus the Carboniferous rocks of the English Pennines must have been elevated after Carboniferous time. Geologists date their rise to Permian time, and presume that there was much Coal at their top when they were raised. There is still a little hill-top Coal in Cumberland.

The Chalk hills were formed at the end of Secondary time, and raised during the beginning of Tertiary time. These are only low; but when we come to discuss very high mountains, like the Alps, we meet new features. The Alps were undoubtedly uplifted during the comparatively recent Miocene period; yet in the Tyrol I have seen masses of Alpine mountains the rock of which was Jurassic—that is to say, millions of years older than the date at which the uplift took place.

Several things have to be remembered. One is that the higher the mountains the more quickly those forces work that are constantly tearing down the tops. The softer modern strata, if raised to an Alpine height, would wear down at a tremendous rate; so that, comparatively soon, there might only be left those more

solid, older rocks that had been hurled up, in the gigantic uplift, from considerable depths. Then, again, we have to face the fact that the Earth-storm that sent up the Alps was one of remarkable force and violence. The rocks are bent, folded, twisted, crumpled, wrenched, and doubled over in such stupendous disturbance that in many places newer rocks have been bent in, with gigantic folds, under the older ones; and we find here some of the rare exceptions to the rule of geological order as stated in Chapter III., and taken for granted in every chapter since. Volcanic rocks, and rocks of Primary, Secondary, and



CONTORTED STRATA, IN SOUTH TYROL.

Tertiary age, are all to be found in the Alps, often jumbled strangely together. This indicates not only highly stressful Earth-movements, but also the continuance of them for a great length of time.

Many years ago, when I was about twelve years old, I was walking along a footpath that ran by the side of a main line of railway; suddenly an express train came hustling along, and I remember still my amazement at the way the ground shook as it passed. I distinctly recollect the thought that this Earth that I had believed so firm and solid, and which stretched out all around me to such huge distances, must after all be far weaker

than I had ever expected possible, to be so shaken by a train which, a few minutes later, was almost out of sight in the vast expanse, so small was it in comparison.

Even in those early days I must have had some of the instincts of a geologist. My deduction was a true one. The crust of the Earth is relatively weak; it lies like a thin skin on the top of a hot pudding, and little bubbles burst through it as the pudding lets off steam. It is of exactly the right strength, however; were it stronger, greater forces would accumulate under it, and in the end there would be a more devastating explosion. Were it weaker . . . You can imagine for yourselves what would happen.

This crust of the Earth is always quivering—just like the skin of a hot pudding—so that land levels never remain absolutely constant. The Temple of Serapis, not far from Naples, was built on the Italian coast over 2,000 years ago. It sunk slowly beneath the sea, remaining submerged for centuries. An earthquake raised it up again, but covered with 40 feet of sediment. The pillar-tops were showing, and it was carefully excavated. An architect sketched the ruins in 1814; but when he returned to see them again, about a score of years later, the temple was sinking slowly under the sea. The fact that the Mediterranean is tideless probably helped to preserve this temple; our children may see it on dry land again.

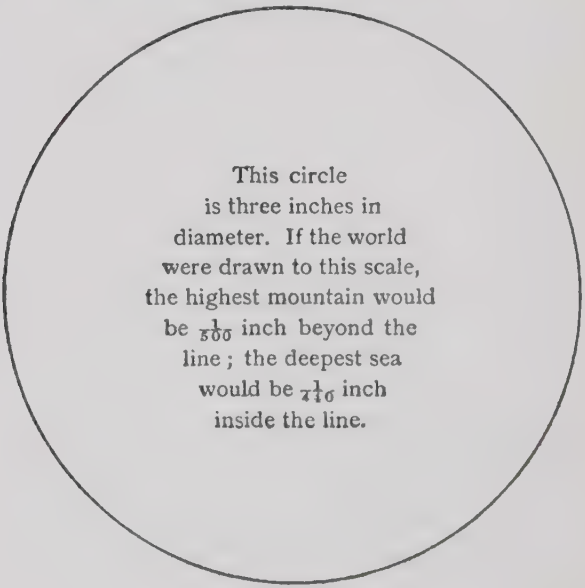
Scientific instruments are made of so delicate a mechanism that we can measure and record the fact that the English Channel sinks regularly under the extra weight of each high tide, and rises to its old position when the tide goes out. The skin of that pudding of which we spoke would similarly sink a trifle if we (carefully) poured water upon it.

The position of the North Pole wanders about a little. I pity the poor traveller who journeyed there, only to find out that he was where the Pole had been last month, but that it had since changed its address! So that all talk of the "Solid Earth" and "Terra Firma" must be taken with a grain of sea-salt.

Some of my friends exclaim: "How tiresome all this is! Why can't the world be a perfect sphere, and done with it!"

Do you want to be a fish? I don't. But if the world were a perfect sphere, we should all of us have to be fishes. Rather over seven-tenths of the surface of the Globe is under the sea. Rather under three-tenths is "dry land." The average depth of the sea is a little more than 11,000 feet. If the Globe were a perfect sphere, it would be covered all over with a uniform depth of about 8,000 feet of sea. Now, are we not all of us glad that it is *not* a perfect sphere?

But it is not far from the absolute round. The Earth's diameter is 8,000 miles; the deepest part of the sea is almost exactly six miles below the surface; the highest mountain is five and a half miles; these are very petty measures compared with the size of the Earth's circumference, 25,000 miles.



Could anyone draw such trifling deviations? Of course not. Yet their effect is all-important to us and to all living things. On these trifling differences in level depend the whole build of the continents, the whole curb set upon the sea.

"Hither shalt thou come, and no farther; here shall thy proud waves be stayed," was said to the sea by that Power that shaped these rugged little irregularities that we call continents, countries, and mountains. To the mighty girth of the world they are as nought; but to the petty stature of Man they are immensities. With endless toil and hazard we drag ourselves, breathless and faint, to the mountain-tops; one geological age ago the sea rolled over those crests.

CHAPTER XI

MOUNTAINS—THE ALPS

To stand high up, breathing the wonderful clear air, amid snow, in summer sunshine, seeing all around you a ring of snow-clad peaks, is one of the most splendid experiences that can fall to the lot of any man.

"Hast thou entered into the treasures of the snow?" That, too, is one of the searching questions asked of Job. The treasures of the snow. What is a mere handful of pearls and diamonds compared to what glistens here from every peak, cliff, and horn? And at daybreak and day-close diamonds will turn to sapphires and rubies, to agates, to beryls, to emeralds, as the snows change tint with the sky. That marvellous sight, seen so well in Switzerland, I have also watched in our dear English mountains in winter, when the white Pennine wall tinted to a hundred lovely tones, and all Nature sang the beauty of light made manifest.

And the flowers of the mountains, gentians and

labiates, stonecrops and pansies—a thousand in colour and shape, dainty loveliness amid tragic rock, melting the mountain sternness with the touch of a baby's hand.

Study the constant fight between Climate and the Proud Peaks. Here, in August, the sun is hot; rock absorbs heat quickly; snow absorbs it slowly. Pick up a piece of rock from the very edge of that glacier; the rock is so hot that you almost drop it in surprise. Imagine the break-up that ensues when a rock is heated by day and frozen by night; the toughest granite would perish.

Consider the heaps of stones, the evidence of rock-falls, of avalanches, and then look at a glacier. What a load of stones it bears on its flanks! And at its finish, what an immense heap it has dropped! All shapes, all colours, all sizes, the fantastic burden of the glacier amazes with its monstrous accumulation. Remorselessly the enemies of the mountains are demanding their daily sacrifice

Here, at the glacier's end, we see a tell-tale sight. We note other rock-heaps to the right, to the left, to the front; what brought them down? Nothing, except this same glacier, when it was larger; it has shrunk; the weather is warmer than it was, perhaps the mountains are already much lowered. Yonder little inn, where we are going for refreshment, is built on a great heap that the glacier obligingly brought down some thousands of years ago.

The air is very light and elastic 12,000 feet up. We feel as if we had dropped a burden that we had before carried all our lives. It is so—the burden of the weight of the air. Here it is not more than two-thirds of its weight at sea-level. At 16,000 feet it is distressing to all except practised mountaineers. Evidence of rock-falls lies all around us; weather conditions change with dangerous rapidity; in especial, thunderstorms strike each mountain wall with heavy bombardment. The very sublimity of the mountains is the sublimity of a great struggle. The enemies of the

mountain batter, and shatter, tear away, wear away; and we think of our British hills, mere stumps of the mountains that bore that furious bombardment on and on for millions of years.

Closely connected with mountain scenery and Geology, we have lakes. These are of several types. There is the small wild lake near the summits or just below the snow-line—anywhere where a rocky trough or hollow forms a natural basin. Such lakes are well known on Snowdon, and there are two below the peak of the Matterhorn. Reflecting as they do the noble majesty of the mountain, these have always a wild, splendid beauty. Then there are the larger lakes of the valleys, such as are seen to admirable advantage in England, Scotland, and Ireland, as well as in Switzerland.

In many cases it is supposed that the hollows that hold these lakes were formed by glacial action. It is still uncertain, but a probable theory. One or more streams run into each of such lakes, and one river runs out of each, at the lowest point. Thus, the Rhone, densely charged with silt, runs into the lovely Lake of Geneva. As it must obviously drop this material into the lake, it runs out, at the far end, a clear stream.

The life of any lake is therefore threatened more speedily than the life of the peaks above it. Two things are happening to the lake: the river is filling it with silt at the upper end, and the rocky barrier essential to it is being gradually worn down at the lower end. Between these two, the lake is ultimately doomed. The Lake of Geneva is smaller than it was when the Romans mapped it. Whenever streams run down into the sides of the lake, they bring silt that makes a small platform; and here will be set a village, and, if the lake be big enough for steamers, a small pier. Note carefully the angle at which the mountain-sides are dipping into the lake. Note also the angle made by the low-lying strip of land on which the lake-side town or village is probably built. You will see for yourself, in almost every case, that these angles

prove two entirely different circumstances. This is so marked that it can easily be seen in pictures or photographs, and not only with reference to lakes that you may have seen, but also with reference to lakes that you have never seen.

Even this simple little detail will make a lake more interesting; you will see its beauties better, because you will be looking at them with a seeing and not a non-seeing eye. Never believe those foolish persons who tell you that the beauty of a thing becomes less

Lake Manipouri, New Zealand.

when you begin to understand it; they might as well say that a book becomes less beautiful when you can read it! But they may tell you that things lose their mystery when they are understood. That, again, is utter foolishness; we never wholly and totally understand anything; what we call "understanding" is just unravelling so much of the mystery of it that the remaining mystery becomes all the more marvellous.

Come up to our lake in the mountains; the day is stormy; inky clouds mantling inky cliffs reflect in the deep mirror of the waters; the wind, whistling shrilly

through a gap, hurls little waterspouts across the surface of the water; they break on the rocks of the far shore. Does it lessen our mystery of beauty to know that countless millions of years ago this rock came pouring, red-hot, from a volcano? That in those days the vast Atlantic was not; that Eastern America was linked to Western Britain? Little lake, leaden-grey and utterly mysterious, were you then here before the Atlantic was formed? And might you yet be here at a time when the Atlantic ceased to be?

We must not forget the glories of the rock itself; for a geologist has missed half the meaning of his work if he be not an ardent lover of the rock. Every mountain rock is noble, be it grey Pennine Limestone, softening to a tender, dove-like shade, as at the Winnats Gorge, or hardening to an almost fierce blue, as in Monsal Dale; Red Devonian, richening to purple, and passing through almost every shade in the palette, till it reaches an eddying series of toned whites, tinted too elusively for description; Dark Volcanic rock, dull yet subtly glistening, in black, green bronze, and oak-bark shades, sombrely splendid. Fawn-brown Sandstone, milk-white Chalk, lavishly mottled Granite—all are beautiful.

In the Alps a wonderful beauty is added to the rock by the frequency with which we find Mica. Mica, which has been spoken of already in Chapter IX., is that glistening mineral which, in a multitude of small flakes, gives its brilliancy to Granite. In many parts of Switzerland and the Tirol, Mica, shining from a million small grains in one rock, gives its silvery lustre to heighten and ennoble the already lovely colouring. Browns, reds, greys, purples, all silvered over with this exquisitely bright transparency, twinkle at us from every cliff and boulder. It is magical; it is the touch of the fairies over the work of the giants.

Many of the world's most notable mountains are Volcanic or Plutonic in core, though there may be sedimentary rock on the lower slopes or outer layers. The Matterhorn is of a gneiss of rich black, touched

with brightness, though not glossy; it has bands, in contrast, of glittering white quartz. Every day the snow lies differently on its steep face; after a snowfall, in quiet weather, all will be white; but the least gust of wind will bring half of this off the bold precipice, and a good wind will expose the whole grim blackness of the gorgeous mountain. The Matterhorn is never twice alike; but every aspect of it is nobler than the last. That lesser height, the Hornli, in front of it, is in strong colour contrast, being a fawny sedimentary rock. Once the whole black core of the Matterhorn was wrapped in that gentler covering—an unborn Matterhorn.

Mont Blanc, that huge rock-mass, is not one mountain, but a dozen. The great bulk of it is pale grey Granite; this is used as building stone in Chamonix. The cross erected on the grave of Whymper, the great climber, is of this fine stone.

Mount Everest, that king of mountains, has a core of yellow Granite; but sedimentary rocks rise well up towards the top of it. It is only in the final height that the Granite towers out of its softer envelope. Such climbers as are able to touch this triumphant Granite at its native height must be reckoned among the first in the world.

Climbers! There is a thrill in the word! But, you may ask, what has Geology to do with climbers? Everything, for the glorious sport of climbing was invented by geologists. In the old days no one troubled to climb to the tops of the great mountains. It would be no use, they said; it would be dangerous; to which some added that there were surely demons and evil spirits up at the top there, who would settle the account of the foolhardy climber, even if he escaped the perils of snow, rock, giddiness, exhaustion, mist, thunder, lightning, and all the other perils of unknown heights. This belief in evil spirits at the heights persisted right up to 1865, when Whymper and his bold party first climbed the Matterhorn, and were mistaken for bogies by the party try-

ing to climb up by the other side, as I tell in my book, "The Joy of Mountains," to which book I refer those who are specially interested in this fascinating aspect of the subject.

It was the geologists who overcame all the above-named fears in their intense desire to learn the secrets of the heights. In 1760, early in the days of Geology as a science, H. B. de Saussure, a clever, enthusiastic young Swiss geologist, offered a reward to anyone who could discover a way to the top of Mont Blanc, which had never in all history been climbed, or even attempted. For twenty-six years lukewarm attempts were made, without success; and only in 1786 was the mountain ascended, by Balmat and Paccard. De Saussure himself followed shortly afterwards, and the first step in a new and wonderful sport was taken.

To-day, climbing being a well-practised sport, no one considers Mont Blanc a difficult climb, though, of course, it calls for some power of endurance. The slopes are easy, as high summits go. Vigorous young women climb "the White Mountain" yearly; to the sort of sporting girl that we are turning out from our co-education and modern girls' schools the thing is not too difficult. But for thousands of years men lived at the foot of this mountain, and no one thought of climbing to the top of it till a geologist put forth the idea. Long live Geology!

In 1802, Alexander von Humboldt, a brilliant young German scientist and geologist, went to South America to explore the Andes, and tried to climb to the top of Chimborazo, which was then believed to be the highest mountain in the world. He and two friends, who were no practised climbers, stuck manfully to the work till the blood slowly oozed from their lips and gums with the effort to breathe. They climbed 19,000 feet, and beat all records at that time.

About 1860 climbing was in full swing, and the science of it was well developed. Tyndall, the English scientist and geologist, and Whymper, artist, writer, sportsman, and enthusiastic amateur geologist, made

records in those days. Whymper climbed Chimborazo (20,500 feet) in 1880, and for a while held the height record.

With two Swiss guides, he climbed Cotopaxi, in the Andes, the highest active volcano in the world, 19,000 feet. They took a tent with them, to stay the night at the top, as Whymper especially wanted to see the crater in the darkness. As soon as night fell, he leaned over that burning pit, with a guide holding on to each of his legs.

Then they tried to sleep. The ground was so hot that their indiarubber ground-sheet melted, and smelt abominably, as burning rubber will. Whymper opened the flap and put out his head, to breathe a little fresh air; immediately his nose was almost frost-bitten! The temperature was 110° F. on the ground, but in the air, only 4 feet above the ground, it was 13°.

Fitzgerald, Mummery, Sir Martin Conway, and others, performed great feats of climbing and added to our knowledge of Geology. At last, in 1922, on Everest, Mallory reached 26,800 feet without artificial oxygen, and Finch and Bruce reached 27,300 feet with artificial oxygen.

It is fully possible that, shortly after this book is in print, British pluck and enterprise may have conquered Mount Everest; but the feat will not exhaust the possibilities of the Himalayas. This vast range, 2,000 miles long, with at least eighty peaks over 24,000 feet high, will keep adventurous spirits busy for a long time to come.

And the man who started all these wonderful adventures, the geologist Saussure, has his statue in the main street of Chamonix, placed so that the eyes look ceaselessly at the summit of the mighty Mont Blanc.

CHAPTER XII

WORLD GEOLOGY AND ITS CONNECTION WITH WORLD HISTORY

THE object of this chapter is to trace, very briefly indeed, the main lines of World Geology, and to show how closely the history of the continents has been affected by their geological structure.

It must be noted that every continent has certain land-blocks of great strength that have defied the ups and downs of geological forces, and have remained permanent throughout geological time. By, between, and in among these massive land-blocks are generally wide plains or shallow seas; these can easily change their character, the seas into plains, or, the plains into seas—changes which have often taken place, and which account for the constant changes of land-formation which Geology so abundantly proves.

The great ocean depths are the opposites and counterparts of the massive land-blocks; and we must presume that these seldom alter, so that, in a world of change, there remain a few permanent features, just as, in human society, there are constant alterations and fluctuations of custom, while certain basic moral principles always remain, the permanent and durable safety-places of the much-vexed human spirit.

> "Love is not love
> Which alters when it alteration finds,
> Or bends, with the remover to remove;
> Oh, no! It is an ever-fixèd mark,
> That looks on tempests and is never shaken. . . ."

It is an instinct with human beings to seek the permanent in a world of constant flux; and I think that it is partly owing to this instinct, so valuable in the moral world, that at first much opposition, scepticism, positive dislike, was aroused by the claim of the geologist that he can prove the gradual but unceasing

give-and-take between things to the common eye so definite and distinctive as continents and oceans. But the physical constitution and fossil contents of the bulk of our land-masses tell an undeniable tale to the patient searcher.

Let us, then, begin our very brief tale of the continents. Europe, as we showed in our second chapter, was, at the end of Secondary time, largely under the sea, in which condition the chalk was being formed. The oldest rocks in the continent are in the north-west, forming that very ancient range that follows down the coast of Norway, through the Shetland Isles, down the west coast of Scotland, and the west coast of Ireland. These stood as mountains in the long-far-off time when there was no North Atlantic, when Britain was joined to the east coast of North America.

As these are a fringe on the very outside of the continent, it is a fair statement to say that Europe as we know it to-day is geologically a very modern, newly-formed continent, with much low-lying plain-land, with many shallow penetrating seas, which are the natural accompaniments of such plains. The position of the mountains is such as does not seriously interfere with travel, while both the plains and seas are so grouped as to encourage it.

This open continent has important coast-lines on the south and on the west, and this feature helps to modify and improve the climate. Owing to the spin of the world being from west to east, all western continental coasts have a great advantage of temperature over all eastern coasts; the full facts explaining this are too complex to be given here.

This continent, shaped for easy travel by land or by sea, is likely to be the home of fine civilisation; for travel is a wonderful educator, which enables each nation, if it be reasonably wise, to learn the best things that its neighbour is doing. Even to-day, with all our books and newspapers to help us, we cannot do without travel if we want to be completely educated.

The geological facts set out above show us why

Europe is a continent of many and splendid harbours; it is inevitable where newly-formed plain-lands rise only a little way out of the sea. Britain alone has more good ports than the whole of Africa. Nearly every European country has a coast and ports. So that the history of Europe is a history of much-travelled, closely related nations living closely together in a small, busy, highly convenient continent, from end to end of which ideas can spread and spread. And the next most logical and necessary step in its development is the preservation of peace by the organisation of this small, handy, busy continent into a real confederation of nations, with a strong central League of Nations, based on justice and Christian ideals. To such a development Geology points; it could well be called the geological logic of the situation.

Coming now to Asia, we are faced with very different factors. We are here dealing with an enormous bulk of land, much of which is ancient. India is the oldest portion; but Arabia, China, and North-Eastern Siberia are very old too. Then those comparatively new mountains, the Himalayas, with their eastern and western extensions, form a huge block, a very serious obstacle; and the Pacific, a recent ocean, the coasts of which are the weakest portion of the Earth's crust, presents a shore-line of earthquakes and volcanoes.

In this stupendous mass of land, India and China, shut in by tremendous walls of mountains, have each developed a civilisation, old, remarkable, worthy of high respect, but far too little tempered by outside influences. Each of these two interesting cultures is essentially that of a land shut in upon itself. They are countries of great importance none the less, and centres of vast populations. Japan has an island civilisation of curious history. Relatively inaccessible till recent times, she first developed on internal lines; then the modern vessels brought her into touch with other nations, and with this change of conditions came a change of ideas. Each one of these three

countries has been affected highly and deeply by its geological conditions. The rest of huge, landlocked Asia is awaiting the days when modern means of transit triumph over the (geological) obstacles in the way of its development.

Africa affords a splendid example of this basic connexion between Geology and History. It contains a larger proportion of solid, ancient blocks of permanent land than any other continent. These rise high out of the sea, with a large average elevation. The coast-plain, derived from these old rocks, is not a very wide one; there have been too few geological changes; the coast-line is not a broken one; there is no breaking-in of any large, useful arm of the sea; there is an absence of good bays or serviceable ports.

That regular coast-line, unbroken and untrained, has offered no hospitality to the ships of civilisation. One of the best ways to explore a country is by its rivers; but owing to the build of Africa all the rivers have formidable falls near the coast, which effectively stop the ships. Right up to my own schooldays the baffling word "Unexplored" was written across old, obstinate, unbroken, untrained Africa. And this, largely, for reasons of its geology.

The heroism and genius of Livingstone brought about, at last, what was inevitable before much longer time had passed. The first White-man to enter the mysteries of Central Africa was a doctor, a missionary, the truest of Christians, a thorough humanist, a fighter of the hideous slave-trade. If we can keep his ideals before us in Africa, we need not fear those who might sneeringly say: "The geology of Africa was right; it was planned to keep out the White-man."

The discovery of America arose through the brilliant, plausible blunder of the great Columbus. He argued that as the world was round, and as Europe ended with an ocean on its west, while Asia ended with an ocean on its east, these two oceans were really one, and Asia lay across the Atlantic. The logic was excellent; but if he had thought to check his calcula-

tions by time, by the simple calculation that in the Mediterranean region the world was circling at a speed of about a thousand miles per hour, he would have recognised that the circumference of the Globe was far larger than his reckoning permitted. Perhaps it is as well that he did not make any such calculation. It seems sometimes better to be wrong bravely than to be right timorously.

He landed first in the West Indies, the very title of which still bears witness to his error. With this part of America I will first deal. The island of Barbados is remarkable as one of the few places where deep-sea oozes (that is to say, the material laid down very slowly at the very deep parts of the bottom of the ocean) are to-day forming part of the land, proving that even the greatest depths may be thus elevated. Barbados was carefully examined by two very able geologists, Mr. Jukes-Brown and Mr. Harrison, who proved that the lowest rocks there were laid down in an estuary; then these sunk below the sea to extraordinary depths, after which the oozes were laid down; then as they gradually rose this frail matter was covered and protected by coral Limestone; and to-day they stand, 1,200 feet above sea-level, forming the highest part of the island. Similar formations have been found in Cuba, one of the first of the American islands to be visited by Columbus. The discovery of the possibility of the very deepest deposits becoming land is very important in Geology.

Coming to the mainland of North America, the eastern mountains form the chief permanent and ancient block. These were once united to Britain, before the North Atlantic was formed. There is an old block also in the west, that once was part of a land that stretched into the present Pacific. The seas between these two blocks were gradually filled in; Atlantic and Pacific oceans were formed; the Rocky Mountains gained a new uplift when the whole of the belt around the Pacific rose; and thus comes modern North America.

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In South America the largest, oldest, solid block forms the highlands of Brazil and Guiana. The Andes are modern, are probably still rising, are very Volcanic, and are closely connected with the intense movements that produced that tremendous trough, the Pacific Ocean. The Pacific is ringed in by mountains and volcanoes, and the colossal shrinkage that caused it to come has brought with it a disturbance that continues to-day. Its mountain barrier between Asia and Australia has probably been shattered by such eruptions and explosions as smashed Krakatoa in 1883. Terrible earthquakes ravaged San Francisco and Valparaiso (Chile) in 1906; while, in the West Indies, Martinique was devastated in 1902 and Kingston (Jamaica) in 1907. Regular earthquakes and eruptions, not necessarily destructive to life, take place round or near the rim of that mighty ocean.

Australia remains to be dealt with. Though certainly once joined to Asia, when the present bridge-like set of islands formed continuous land round the unstable Pacific, it has been broken away for what, to us, would appear an immensely long period of time. Thus rendered remote from the fiercer competition that raged in the larger land-blocks, its aborigines and its animals remained in a backward state till the spirit of adventure began to link it to the remoter lands of the White man. Western Australia is its oldest portion, and has perhaps never been submerged. Other parts of the continent have been up and down several times, and over the sandy central desert the sea probably rolled in comparatively recent times. But for the geologist its main interest lies in its affording a home for primitive creatures whom the rush of life has caused to disappear elsewhere—especially that truly extraordinary creature, the Platypus, a curious animal of the primitive type called Monotreme, which still lives in some numbers by the creeks and rivers of the central parts of Queensland. It swims like a water-rat, but lays its white egg, like a bird or reptile, in a hole in the bank, and there hatches it out. But

as soon as the young one appears, the mother suckles it like a mammal! They are shy and harmless creatures, intensely interesting as a link between classes now thoroughly distinct. They have only continued to exist because they found a land where the "struggle for existence" was not tense.

Another interesting Australian survival is the lung-fish, which has lungs as well as gills, and so is able to live on in the mud in dry seasons when the river ceases altogether. Such fish were common in the Jurassic period, along with the many huge reptiles whose long names end in "saurus." To-day only a few lung-fish exist, in out-of-the-way parts of Australia, Africa, and South America. Are the world's rivers less liable to dry up than they were in Jurassic times?

Here I must end my too short notes as to the general shaping of the present continents. But now let me briefly show how this scheme of solid blocks amidst varying areas works out in geological history. A dry-land connexion between Asia and North America, where Behring Straits now run, is clearly suggested by the striking similarity between Mongol and Red-skin types. Rocks and distribution of fossils suggest a time when the permanent blocks of Brazil, Africa, India, and Western Australia were all joined. That Australia was joined to India not too long ago is evident. In Silurian times, Mr. Bailey Willis argues that nearly all North America was under the sea, the exception being the bolder eastern blocks, shown as three very large islands, and two other island blocks towards the west. In Ordovician times, Professor Frech argues that the bulk of Asia was under water, excepting the very north and India and Arabia, these latter two being joined to Africa on the one side and to Australia on the other. And for every proposition these learned men advance a large amount of proof.

There is something, indeed, awe-inspiring about such vast changes, and the immense slice of time needed to bring them about. I have found many who

gain a real solace from Geology, a feeling that the sorrows of life are but petty and transitory when compared with such immensities. Others, again, like the man mentioned in Chapter IV., become disturbed, alarmed.

In the finest hymn that Dr. Watts ever wrote, a hymn that has been sung on highly solemn occasions, and that takes rank, in the eyes of many, as a national invocation, appear the words:

> "Before the hills in order stood,
> Or earth received her frame,
> From everlasting thou art God,
> To endless years the same."

When these lines were written, Geology was little understood; and Dr. Watts, wishing to assert with solemn strength the eternity of the Creator, speaks of before even the hills and mountains were ranged in their order. Geology would treble and then treble that again; it would tell us of a succession of orders of mountains; not of one order, but of several. The prospect is the more sublime, the awe the more unspeakable.

Time, in a majestic procession, passes before the dazzled, half-blinded eyes of the geologist. So vast is that procession of the Ages that he cannot hope to realise it; something infinitely beyond his imagination is yet stretching that imagination wider and wider. What lies behind that pageant of incomparable stateliness we only vaguely guess; Watts has guessed at it in the lines quoted above, without having realised the visions of Geology. And one of our great poetesses similarly guessed at it, shortly before her death—guessed at it with more lyric fervour than Dr. Watts displays, in lines that everyone should know. For these are not merely words; they reveal the soul of Emily Brontë, who uttered them:

> "Though earth and man were gone,
> And suns and universes ceased to be,
> And Thou were left alone,
> Every existence would exist in Thee!"

CHAPTER XIII

FIELD-WORK AND FOSSILS

If the previous twelve chapters have the effect that I wish, the reader will now be eager for any field-work that lies within his scope; for Geology without field-work is like making love on the telephone to a girl whom you have never seen face to face.

For purposes of practical Geology, it is very necessary to find "exposures" and "outcrops"—that is to say, places where the actual rocks are exposed. These may be found in the shape of cliffs, either by sea or land—quarries, brick-fields, railway cuttings, road-excavations, or any similar laying bare of the rock, either natural or artificial. It will be seen at once that sea-coast or mountain-range offers special opportunities. But such exposures do not give the only opportunities of studying Geology. River-action, which is of the utmost importance, can be studied quite apart from rock-exposure, though where the river runs more or less deeply there is exposure as well. To find the source of a mountain-stream is a real adventure in Geology, and a health-giving experience as well. Current action can be studied along a sea-coast, independent of the formation of the cliffs. Note how the larger stuff is thrown on to the open beach, while the smaller particles are swept into the sheltered bays, which the sea only enters with partly spent force; this is of the very essence of the question.

On a railway journey quite a good deal can be done from the carriage-window, with the aid of a geological map. Study your map beforehand, and know what to look for. Note the shape of every hill or mountain, and link it up with the rock-formation. Note the chief botanical features, especially the trees, and connect them up also. In the Eocene, note how oaks and elms take the place of pines and birches when clay

succeeds sand; and observe how the beech is the chief tree that can live on the chalk. Do you not know that two of our counties have their very names derived from their Geology?—Buckingham, the home of the beech, being, of course, a chalk county, and Berkshire, the shire of the birch, being a sandy county. (The fact that our leading English school is just outside the shire of the birch, though on the borders of it, is a matter for the moralist, not for the geologist.)

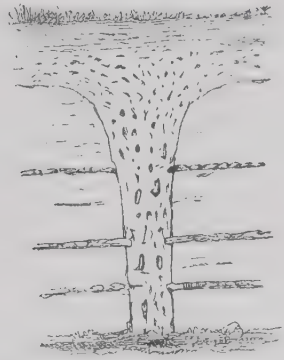
And do not hesitate at rough scrambles or shun mild adventures. If you are young, you should love such sport; and if you have begun to think yourself old, give up so bad a habit instantly. You should see Dr. Evans, at the age of sixty, tackling a dangerous little bit of cliff in Devon, or Mr. Whitaker, aged only eighty-six, finishing up a ten-mile ramble with the Geologists' Association. "We must not let the boys pass us," he says to his companion, and the pace becomes hot. That is the spirit in which he has won his triumphs in Geology.

And that reminds me—why not join the Geologists' Association? The subscription is small, only ten shillings a year, and it is one of the most alive bodies that I know. Excursions are arranged for the London district every alternate Saturday, usually; each of these is led by a really expert geologist, with the patience of Job and the politeness of a French marquis. At Easter, Whitsun, and in August, longer excursions are planned, each led by professors of eminence in the subject. My holidays with the geologists have been among my happiest.

If you are a teacher of Geography, certainly add Geology. It forms the scientific basis of all Geography; children love it (if properly presented to them, of course); it involves any amount of smart and careful thinking; it is and will be increasingly recognised as of great utility. Not so very long ago an eminent water-board began a reservoir without sufficient geological advice, and found that they had placed it in a position where the rock was not watertight!

How much money was wasted I do not know; but being public money, it was nobody's business because it was everybody's business!

Begin a rock collection at once, and do not hesitate to begin it with what would be called "common stones." There is no such thing, really, as a "common" stone; every stone is a symbol, and has a story. Heaps of road-repairing material often yield fine specimens; the scrap-heap of a monumental mason is a rare Tom Tiddler's ground, and I have yet to find the mason who will not help the enquirer; for the mason loves the splendid stuff that he is handling,



SAND-PIPE IN CHALK WITH FLINTS.

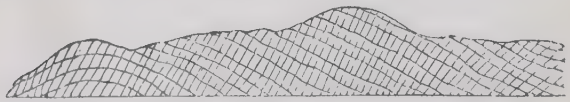
just as the true teacher loves the human material of his daily work.

You need not go, at first, for the rarer minerals; try to get Granite, Basalt, Limestone, Gritstone, Sandstone, and several sorts of each. White sparkling Carrara from the mason's yard will give an aristocratic distinction, the "smiling duchess" touch; but don't despise your humble flints in consequence. Collect all you can yourself; but there will still be some that you will want that you cannot hope to find. These you will be able to buy very reasonably at Messrs. Murby and Company's place, 1, Fleet Lane, near

Ludgate Hill. Geological tools and equipment can also be got there.

After reading this popular introduction to the subject, you will want further books, I hope; more technical books will not daunt you now. There are many good ones, so that I hesitate to advise; two very sound ones are Gardiner's "Introduction to Geology," published by Messrs. Bell and Sons; and Dr. Wilmore's "Geology" in Macmillan's handy little series of First Books of Science. There are very many more that I could safely recommend, but I fear that I might only confuse by too long a list. The two named are of moderate price, and careful in detail.

What about the collection of fossils? This is a fine hobby, and right in the centre of our subject. Fossils



CLEAVAGE AND BEDDING.

The lines sloping from right to left are cleavage planes, the others bedding.

are far more commonly found than the average man has any idea of; they may be in your marble mantelpiece, in the marble top of your washstand, or even in your front doorsteps, if these are natural stone. I know one house well where each of the eight steps up to the front door shows undoubted shells, cut across by the saw of the quarry. But, obviously, these cannot be "collected."

One can easily combine a seaside holiday with a geological one by visiting some place, such as Whitby, Lyme Regis, Hunstanton, or Folkestone (there are very many others), where fossils are plentiful. The beach may provide specimens without the somewhat hard task of getting them by hammer and chisel out of the solid rock. But quarries are splendid hunting-grounds. Quarries in Limestone sometimes offer,

without exaggeration, many thousands of specimens. Limestone is the most certain hunting-ground.

What will be easiest found are the shells, or internal casts of shells. An internal cast is formed naturally as follows: The shellfish has died millions of years ago. His dead shell has been filled up, probably by limy sand, sometimes by other mixtures, just as one finds to-day dead cockle-shells and mussel-shells in plenty filled up with limy sand. This natural cement has hardened, and later on the actual shell has completely dissolved. The cast remains in the rock; carefully extracted, it is an object of great interest and beauty.

After the shells, corals are common, and crinoids—that is to say, parts of the sea-lilies that were so plentiful throughout geological time. The perfect encrinite is a thing of great beauty, but all that one commonly finds are parts—round stems of about the thickness of a pencil, with an obvious hole in the centre, exceedingly plentiful. Some of the corals are wonderfully beautiful. There are many sorts; once two or three are seen, others will be easily recognised.

Bones, whether of fish or animal, are far scarcer, and you will be lucky indeed if you find them. Sharks' teeth are common in places; remember that a tooth resists decay more effectively than a bone, though our own experience, with human teeth in our own jaws, may not seem to bear this out!

If you are sufficiently scientific, by all means find out their correct Latin names, through a book, a visit to a museum, or through a learned friend. But if "Shell," "Crinoid," "Coral," "Sponge," is enough for you, at any rate keep the knowledge of the exact place where the fossil was found, and the exact rock from which it came. This is far more important than the Latin name; without knowledge of the rock of origin there can be nothing but confusion in a collection. So, for this purpose, I print overleaf a list of the Eras, Systems, and Sub-divisions, beginning with the earliest:

TABLE OF ROCK SYSTEMS.

First Era: Archeozoic, or Eozoic, or Archean.

Immeasurably ancient Metamorphic Rocks ... ... } No certain Fossils.
A few very ancient Sandstones called "Pre-Cambrian" } Intense Volcanic Stress.

Well seen in Highlands of Scotland.

	System.	*Subdivisions.*	*Fossil Notes.*	*Volcanic Stress.*	*Where Well Seen.*
First Fossil-Bearing Era: Paleozoic or Primary.	Cambrian.	Harlech, Menevian, Lingula, Tremadoc.	Large variety; lower forms of life.	Decreasing.	Wales.
	Ordovician.	Arenig, Llandeilo, Bala	Very many; Trilobites common.	Intense.	Wales, South Scotland, Cumberland.
	Silurian.	Llandovery, Wenlock, Ludlow.	Fishes now found.	Quiet.	Wales, South Scotland, Furness, Salop.
	Devonian and Old Red Rocks.	Lower, Middle, Upper.	Many land-plants found.	Active.	Devon, South Wales, Perthshire, Forfarshire.
	Carboniferous.	Carboniferous Limestone, Millstone Grit, Culm, Coal-measures.	Amphibians, Insects; abundant land-plants.	At first, quiet; afterwards active.	South Wales, Derbyshire, Yorkshire, Lancashire, Durham, Northumberland, Valleys of Forth and Clyde.
	Permian.	New Red Sandstone, Magnesian Limestone.	Reptiles.	Considerable.	Devon, Yorkshire, Cumberland.

Second Fossil-Bearing Era: Mesozoic or Secondary.	Triassic.	Bunter, Keuper, Rhætic.	Higher Reptiles, early Mammals.	During this whole era, covering millions of years, there was, as far as we can trace, no volcanic activity in Britain.	Secondary rocks cover a great deal of S.E. England, east of a line drawn from Lyme Regis (Dorset) to Hartlepool. The earlier ones on the west, the later ones on the east.
	Jurassic.	Lower and Upper Lias, Oolite, Oxford Clay, Coral Rag, Kimmeridge Clay, Portland Stone, Purbeck.	Reptiles common, many being huge; Archæopteryx, the link between reptiles and birds.		
	Cretaceous.	Wealden, Lower Greensand; Gault, Upper Greensand; Lower and Upper Chalk.	True birds begin, also flowering plants.		
Third Fossil-Bearing Era: Cainozoic or Tertiary.	Eocene.	Thanet Sands, Woolwich Beds, London Clay, Claygate Sand and Clay, Bagshot Sand.	Mammals become plentiful, though not quite of modern type; modern plants and trees begin to appear.	Great Volcanic disturbance; Europe slowly rising from the Chalk sea.	East Dorset, South Hampshire, North Surrey, Middlesex, Essex.
	Oligocene.	Headon, Osborne, Bembridge, Hempstead.	Approaching more to modern types.	Somewhat quieter.	South Hampshire, Isle of Wight.
	Miocene.	Lenham Beds of Kent (?).	More and more like modern types.	A great mountain-building period; Alps, Himalayas, Andes, etc., slowly pushed up.	Either entirely missing from Britain, or very scarce.
	Pliocene.	Coralline Crag; Red, Shelly Crags; Norfolk Forest Beds.	Mastodon and elephant appear; possibly early remains of Man.		East Norfolk, East Suffolk.
	Pleistocene.	Valley Gravels, Glacial Deposits.	Certainly early remains of Man; stone tools.	Glacial period.	The Great Ice-Age, leaving traces in nearly every part.
	Holocene.	Rocks now being formed.	Modern.	Luckily quiet in Britain!	Various places round the coast.

It will be noted that just as more than one indication is needed in a personal address, so more than one indication is needed to describe a fossil. Examples:

Address of a Friend.	*Description of a Fossil.*
Miss G. Ollergist,	Coral, *Isastræa Explanata*,
Fossil Den,	Coral Rag,
Rockside Road,	Shellingford (Berks),
Quarrytown,	Jurassic,
Somesuchshire.	Secondary Era.

CHAPTER XIV

GOOD-BYE AND GOOD LUCK

I SET out with one compound object in view—to present the groundwork of Geology to you in such a form that all of it might interest and nothing repel; to show the larger aspects that grow out of the magnificent assemblage of its imposing details; to link it to life and to the human soul.

Do not say that I have here stated three objects. Only three aspects of one and the same object, the main object of this book. About the very last thing in my mind was the possibility of this book being used to prepare anybody for an examination. But by a curious coincidence I was looking over the various papers for the London Matriculation Examination just as I was finishing my MS.; among others, I read the very fair, interesting, practical, sporting paper set for Geology; and all of a sudden it occurred to me that this paper could be answered by anyone who had carefully studied this book, and had done the necessary practical work recommended by me in it. This discovery surprised and delighted me. You may take it as a compliment to the book, or to the examiner, or to neither, or to both. But it remains a fact, and I think it is worth while to assure ourselves of its reality.

LONDON MATRICULATION, JANUARY, 1923

Examiner: A. J. Maslen, Esq., F.G.S., F.L.S.

(*Answer six questions only.*)

Part I.—Answer Two Questions.

1. Give a short description of any sedimentary rocks which you have studied in quarries or cliff-sections. Name the districts where the strata you describe were seen, and refer each to its geological system or formation.

2. By what simple characters would you identify the following: (*a*) A nodule of Iron Pyrites or Marcasite; (*b*) a thin cleavage-flake of Mica; (*c*) a crystal of Gypsum; (*d*) a thick cleavage-piece of clear Calcite; and (*e*) the Felspar in a Granite? State the chemical composition of each of these minerals.

3. Sketch and briefly describe *five* common fossils derived from any one formation (such as the Chalk, Carboniferous Limestone, or Wenlock Limestone), and of which you have examined specimens.

Question 1 is dealt with in Chapters I, II, III, IV, V, VI, or VII, taken in connexion with the list in Chapter XIII, and, of course, also with the field-work recommended in that chapter. Again let me point out what a fair, practical, sporting question it is. This gives you a chance; it is no cunning attempt to catch you; it opens out an opportunity. Your true geologist is a sportsman, and behaves as such.

Question 2.—(*a*) is dealt with in Chapter I, p. 13; (*b*) in Chapter IX and in Chapter XI, p. 93; (*c*) in Chapter I; (*d*) not at all; (*e*) in Chapter IX.

Question 3.—Field-work, aided by Chapters I, II, III, IV, V, VI, VII, XIII.

Part II, from which four questions have to be answered, begins with a question on waterfalls, asking for diagrams in illustration. Chapter IX, p. 76, gives the key to this; but field-work, observation, and common sense are also needed. The habit of keeping a sketch-book for diagrams is to be recommended. Then follows a question referring to Metamorphic rocks. These are dealt with very briefly in Chapter VII, but

the subject is a very wide one, and could not be more than suggested in a book of the scope of this one. Note, however, that the candidate has only to answer six questions out of nine. Next comes a very practical and interesting question about water passing through rocks and reappearing. This I have dealt with rather fully; see Chapters I, II, IV, and V, pp. 15, 18, 23, 41, 49, noting also the diagram on p. 19.

The following question deals with *dip*, *strike*, and *outcrop*. See Chapters V, IX, and XIII, pp. 46, 72, 105.

The eighth question of the paper asks for the chemical composition and geological history of Limestone, Sandstone, and Clay. See the first five chapters of this book.

The last question deals with the evidence of volcanoes in the British area. This is sufficiently dealt with in Chapters IX and X.

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Pleased though I am that these pages so nearly hit what an excellent judge considers to be a fair Matriculation standard, I repeat that it was with no idea of this sort that I wrote my book, nor do I claim that it would invariably stand such a test. Any examination is bound to be a test of actual knowledge; but for the aims that are central and essential to this book of mine, knowledge is but a means to an end, a revelation of the larger aspects behind.

Shadowy though these aspects are by their very vastness, they are essential to any large scheme of the destiny of Man. This is the absolute lesson of that wonderful Book of Job to which I referred in my Introduction. The adoration of the wonder and beauty of the Universe is an essential of all Faith. It is, indeed, Faith proven, Faith made actual, logical, luminous. Here, as I write this, that somewhat rare but always beautiful sight, a solar rainbow, is adding its note of beauty to the pageantry of the heavens, whilst I, intent on the beauty interpreted to us the more largely by Geology, am studying the beauty, no less wonderful, of the Earth.

For unless your Geology is linked up with wonder

and beauty it is lacking in its essentials. Wonder and beauty are keynote and dominant, Doh and Soh of the geological scale. And always we come back to Man, his needs and his history. Man's fate and future, faith, hope, and love, are linked closely with the story of the Earth that he inhabits. Man and the Earth have acted and reacted on one another throughout all human history. Every true worshipper sees God in the Universe, and sees the Universe as interpreted by an Earth-dweller.

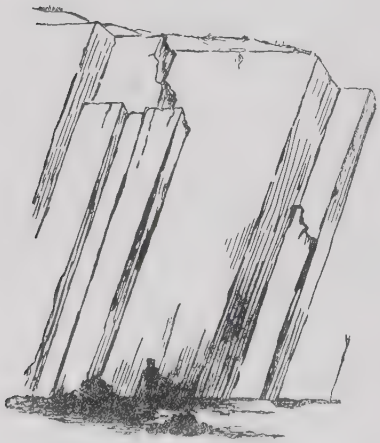
For Man is curiously like the Earth where he lives. His mind and soul are even as the Sedimentary and Volcanic rocks, formed out of ancient ideas broken up and perpetually recast, interwoven with messages of fire. And in them are countless fossils, accumulated during his long history. Dark, reptilian forms are not absent; but the order is one of perpetual mounting, mounting, higher, higher; the lower forms fade, and the figure of the Man of Love becomes ever clearer and more clear.

To the older knowledge, to the knowledge that sufficed the inspired genius who wrote the Book of Job, we have added a new knowledge, that of Geology. And in that new knowledge I see again the wisdom of that ancient book. Again the Voice of God answers us out of the whirlwind, scattering our petty doubts and minor troubles as an impetuous cyclone scatters autumn leaves. Again we are offered for our contemplation the larger pageant of Nature, in all its grandeur and ecstasy, only with a newer vastness and wonder. Again we see Behemoth; but not Behemoth alone; we see behind him a host of marvellous ancestors from whom he slowly developed. Again we see the swift horse and the mounting eagle; the lion in his fierceness; leviathan in his mighty bulk; but we know also the marvellous line of ancestry that evolved these splendid creatures from the reptile that wallowed in the slime.

Again we can revel in superb pride that we are gifted to know these wondrous secrets, however vaguely; to

enter into this universal life, however humbly. Between this pride and this humility, our petty troubles are ground as between the upper and the lower millstone, till, with the writer of that supreme poem, we cry out, chant, sing, the eternal verses:

"Where wast thou when I laid the foundations of the earth? . . .
When the morning stars sang together,
And all the sons of God shouted for joy?"



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